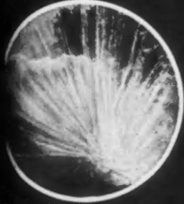
CHEMISTRY



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Isolation Between Scientists

➤ WHAT HAPPENS when two groups of able scientists work on the same problem in isolation from each other? We are now witnessing a vast "experiment in isolation," which should answer this question. Able scientists in the United States and in Russia are now working on the same problems, and there is very little communication between them, chiefly because of military security regulations.

The work reported in this month's CHEMISTRY on power from nuclear fusion was highly classified for several years. The Russians declassified their work first, in April 1956, and nearly a year later, the Americans followed. Neither side is telling all it knows. However, it is clear that the Americans and the Russians are duplicating each other's work, using much the same techniques, and are discovering the same knowledge independently.

It is unfortunate that the forces that isolate scientists working on classified projects spill over into many other fields. Dr. Selman A. Waksman, discoverer of streptomycin and Nobel prize winner, recently charged that the Cold War is interfering with the war against disease. He cited the antibiotic "grisein" discovered in America in 1946. Recently, grisein has been proved to be identical to "albomycin", which was independently discovered in 1951 by Russian scientists.

In this case, Dr. Waksman said, research was needlessly duplicated because of "scientific isolationism, which may even be colored by scientific nationalism." He urged the creation of an International Antibiotics Board to act as a clearinghouse for all antibiotic research being carried on all over the world.

The results so far from the "experiment in isolation" seem to show that no nation can prevent another from learning the secrets of nature. On the other hand, isolation means that scientific work is duplicated, and this inevitably slows down the rate at which new knowledge is discovered.

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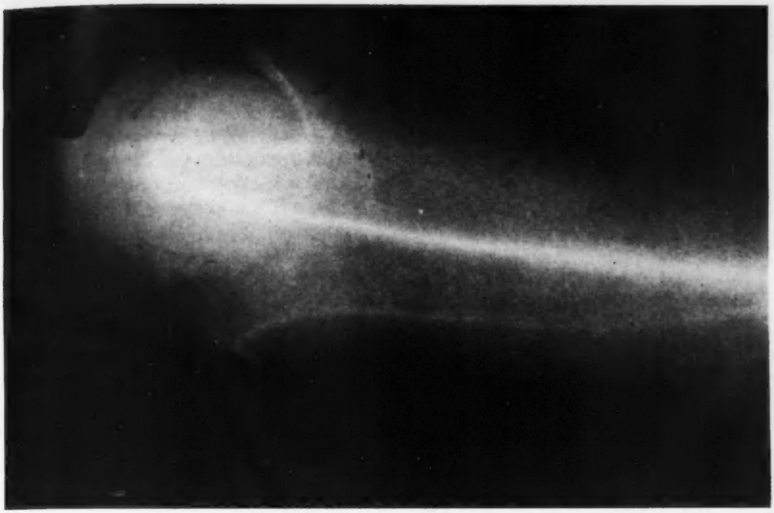


➤ "Pinch Effect" — *This photograph shows the "pinch" going around a curve in xenon gas in an early Perhapsatron torus, which is a doughnut-shaped apparatus, Atomic Energy Commission photograph. The Perhapsatron was used in 1952 and 1953 at Los Alamos to study the pinch effect.*

Fusion for Power

The possibility of obtaining power through the peaceful harnessing of the H-bomb reaction — fusion of light chemical elements — is perhaps the most exciting phase of nuclear research today. Chairman Lewis L. Strauss of the U. S. Atomic Energy Commission in a recent statement, extracted below, told about AEC research under the code name Sherwood. This is the most complete general presentation of the U. S. projects on peaceful fusion that has yet been made.

➤ The Atomic Energy Commission's Sherwood program is a research into the long-range possibilities of controlling the fusion reaction for peaceful purposes, particularly for power production. . . .

Power from fission is here today — a constantly expanding reality.

Power from fusion is a hope of the future — the somewhat distant future. Therefore the two have little or no present relationship.

Sherwood is a long-range, tentative program and it is my belief that every dollar now being invested in atomic power plants using the fission process will have been amortized long before controlled fusion is found to

be either economically feasible or infeasible. In terms of power production, there is no competition between fission and fusion.

We are presently building the "first generation" of fission power reactors which promise, within the foreseeable future, to provide electric power competitive with kilowatts produced from our plentiful supplies of conventional fuels. Power from controlled fusion, on the other hand, is a hope and a challenge looking ahead many years to the time when our reserves of conventional fuels will be nearing the point of exhaustion.

Sherwood Research

I recently returned from a visit to the Commission's laboratories at Los Alamos and at Livermore, California, where I saw some of the important portions of the Sherwood research and discussed the program with the scientists in charge. Other important Sherwood research is being conducted at Princeton University, New York University, and the Commission's Oak Ridge National Laboratory. Supporting research is done by several other institutions, both academic and industrial. I returned to Washington encouraged and more confident than ever that the difficulties in the way of controlled fusion eventually will be overcome. Let me hasten to add, however, that success may be years away. And even after we have solved the underlying scientific problems, more years will pass before we are able to build and operate a commercial reactor using the fusion process. There has been nothing yet that could be described as a major break-through.

However, encouraging progress is being made and certain discoveries are narrowing our approach to the major scientific problems involved. . .

There are baffling problems in trying to find the key to the production of power by fusing together, in a sustained controlled process, the light nuclei at the low end of the periodic table.

This process of energy release is believed to be similar to that which constitutes the source of the sun's energy. Since practically all of the energy we use on earth today comes from the sun, either directly or indirectly, it is obvious that if we could in some way imitate the process of the sun, our problems of light, heat and power would be solved. We have produced *uncontrolled* energy by fusion reactions in our weapons program, just as we long ago produced uncontrolled fission energy reactions. It is a natural sequence to our successful production of controlled fission energy that we should seek to produce *controlled fusion,* i.e., thermonuclear reactions.

The secret of the sun's thermonuclear reactions is believed to lie in the fact that gravitation provides a means for holding the reacting particles of hot gas together even at temperatures of 50,000,000 degrees Fahrenheit. If we could operate a reactor in a similar way, our major difficulties would be solved, but there is no prospect of this.

Better Than Sun Fuel

We do, however, have better fuel than that used by the sun to generate its energy. In the interior of the sun, the nuclei of ordinary hydrogen are fused in a fiery hot crucible to form helium. We have deuterium available, or we might use tritium — deuterium

being the heavy hydrogen isotope and tritium an even heavier hydrogen isotope which does not occur naturally but can be produced in nuclear reactors. Deuterium is available from the ocean in what is, for our purposes, virtually limitless quantities.

However, to reproduce the process on earth, using the heavier varieties of hydrogen, will require very high temperatures — 100,000,000 degrees or more. Obviously, there is no material from which to make a container able to stand up under such temperatures. The most heat resistant materials known would vaporize in an instant.

So we cannot think of this challenge in the ordinary sense of building a containing vessel.

Of course, at any temperature approaching those mentioned, we will not be working with a solid or liquid fuel. We will have a hot gas, composed almost entirely of hydrogen isotopes because any other gas would cause too much loss of usable energy by the process of radiation. At such high temperatures this gas is completely ionized, that is to say, the atoms are torn apart into positively-charged nuclei (or ions) and negatively-charged electrons. The scientists call such a gas a "plasma', or hot ionized gas.

Confining Reaction Is Problem

Now the problem becomes: how can we confine this plasma and keep it at extremely high temperatures? How can we contain it in some manner so that we can raise its temperature to the nuclear ignition point?

Since we know of no material able to withstand such intense heat, we must think of a container in entirely different terms. Whatever the container, or tube, may be, the hot gas must be kept from striking its walls. For in that event, the gas would give up its kinetic energy and the reaction would come to a stop for lack of enough heat.

In our efforts to find the answer to this problem of containing the plasma, or ionized gas, the Commission has approved plans for the design and construction of a large experimental device for research into controlled thermonuclear reactions at the Forrestal Research Center at Princeton University.

It should be emphasized that the device, named the Model C Stellarator, will not be a pilot plant or prototype thermonuclear power plant. It will be exclusively a research tool, making possible experimental work which cannot be performed as effectively with smaller models.

Architect-engineering work for construction of supporting office and laboratory facilities will begin this summer, subject to Congressional authorization and appropriation. It is expected that construction of facilities to house the device will begin in 1958 and that experiments with the Stellarator will begin late in 1960 or in 1861.

New Fusion Machine

The Stellarator consists essentially of a hollow tube containing the ionized gas. Around the tube are external coils which produce a magnetic field to confine the gas. The objective of the research program is to heat the gas to temperatures of millions of degrees and at the same time to confine the heated gas within the tube for sufficient time to allow fusion reactions to take place.

The name Stellarator, of course, is a coined word from "stellar" and "generator".

The scientists at Princeton have been engaged since 1951 in the controlled fusion research program under contract with the Commission. In addition to theoretical work, the Princeton scientists have conducted extensive experimentation with small Stellarator models.

The controlled thermonuclear project at Princeton is under the direction of Prof. Lyman Spitzer, Jr., and the work is under the general supervision of a committee headed by Dr. H. D. Smyth, formerly a member of the Atomic Energy Commission.

The decision to build the Model C Stellarator is in line with the Commission's policy to pursue all promising and feasible avenues of thermonuclear research. At present, it is not yet possible to determine which particular line of research offers the greatest promise of achieving our ultimate goal.

In seeking the means of heating and confining the ionized gas, the scientists in the Sherwood program are working with what some of them have termed a "magnetic bottle."

Electrically-charged particles can be controlled by magnetic lines of force, supplied by suitable coils or by powerful electrical currents passing through the plasma itself.

The magnetic lines of force cause any ionized particle to be deflected whenever it tries to cross them. The particles, instead of crossing the lines, are compelled to spiral around them. Thus, with the "magnetic bottle" we seek to throw up invisible barriers to prevent the plasma from coming into contact with the walls of the tube so far as is possible.

The scientists believe it will be possible, in such a system, to contain the plasma at a temperature of more than 100,000,000 degrees, while the walls of the container remain relatively cool, or at least well below the melting point of the material.

Here we come up against another baffling problem, perhaps the most difficult problem of all.

How do we set about making the "magnetic bottle" as nearly leakproof as possible?

When the magnetic lines are employed as barriers against escape of the plasma, pressure is built up inside the lines with resulting instability of the plasma. The lines behave much like rubber bands. They are inclined to bend inward and let the plasma flow out around them.

Our scientists are hard at work at the present time on this problem of instability.

The magnetism must be just strong enough to confine the ionized gas at the right density and temperature and to maintain that confinement long enough for a reaction to take place. Since the reaction raises the temperature, the magnetic field must have variable qualities. It must grow stronger when necessary to keep things in balance. We must be able to draw power out of the thermonuclear machine without disturbing its tricky balance.

Pinch Effect Used

In our research on this particular problem, some of our scientists are working with what is known, in the parlance of the laboratory, as the "pinch effect". They are trying to

regulate the strength of the magnetic field, and obtain a direct interplay between the magnetic energy and the energy of the plasma; in other words, to produce a balance.

A heavy current, such as a bolt of lightning, can squash a copper drain pipe through which it passes. The "pinch" is the same phenomenon in a gaseous discharge. This is based on the familiar fact that parallel circuits carrying current in the same direction attract each other.

In applying this fact to controlled thermonuclear research, the scientists are seeking, through heavy discharges of electricity, to "pinch" the atoms of the plasma together and suspend them in a thin line away from the walls of the container.

Interesting results are being obtained in this particular effort, but the problem is far from being licked; perhaps even years from its ultimate solution.

We have produced very high temperatures for the briefest fraction of time from these "pinched" discharges. But the time during which these can be maintained, at present, is reckoned only in microseconds. As yet, the "pinch" is not fully stable.

And, of course, to be valuable for the purposes of producing power, the atoms to be fused together must be held in a tight bundle long enough and at a temperature high enough for an appreciable number of them to fuse. Furthermore, the energy output must far exceed the amount of energy that is required to produce the reaction.

We are making progress, but the problems are formidable. It may be many years before we are able to utilize the deuterium of the ocean to produce electrical power and to provide us with a virtually inexhaustible source of energy, a source which may be sufficient for generations to come.

I find myself in agreement with the scientist who was quoted the other day as saying:

"Anyone who thinks fusion cannot be controlled is a fool; but anyone who thinks it is going to be easy is an idiot."

Fusion Power Possible

We are no longer in the stage of wishful thinking; we are in the midst of very serious research. We will not have economic power from fusion in the near future, but we have great hope that eventually it will come.

One thing we have succeeded in doing. We have already short-circuited that stage which was reached in the nineteenth century when some scientists of that day decided they had proved that it was entirely *impossible* to make a machine that could sustain its weight in flight.

No significant opportunity for enlarging or accelerating our research is being overlooked.

For example, in 1953, only a handful of scientists and engineers, not more than 20, were engaged in the search for the key to controlled fusion. Today, approximately 500 persons make up the Sherwood program, including about 250 scientists and engineers.

The amount of money devoted to the research on controlled fusion has been sharply increased each year since 1953. In 1954 expenditures of the preceeding year were tripled. They were increased again in 1955 and in

the current fiscal year we are spending more than 20 times the amount spent in 1953.

Industry is keeping abreast of the work too. At the present time American firms and individuals are in touch with the program through 63 access permits issued by the Commission.

Many years of intensive work may be required to develop a thermonuclear device which would yield more energy than it consumes. And after that, we would expect to spend more years developing a full-scale power producer, able to compete with conventional fuels.

But the rewards are so great as to warrant large investment of money, time and talent.

One KgD = 100,000 KWH

For one thing, the total fusion of just one kilogram of deuterium would yield energy on the order of 100,000,000 kilowatt hours. A full-scale controlled thermonuclear device would contain only a minute amount of fuel in the reactor chamber at any time. As a result of this very small fuel load, the possibility of an explosion or loss of control would be extremely small.

While a fusion reactor may make its own parts moderately radioactive, waste disposal problems such as those created by fission products would not be encountered.

Finally, if we solve the problems of controlled fusion we may find that, at the same time, we have partly solved the problem of converting nuclear energy directly into electrical kilowatts. We may find that, to a large extent, we have avoided the very costly and inefficient cycle of heat exchange. This possibility arises because some of the energy released in the fusion process might be handed over directly to suitable electrical circuits. The confining field is itself electromagnetic in character, so it may be possible to devise ways so that the interaction of the released energy back on the confining field could, under proper conditions, be used directly for generating electric power.

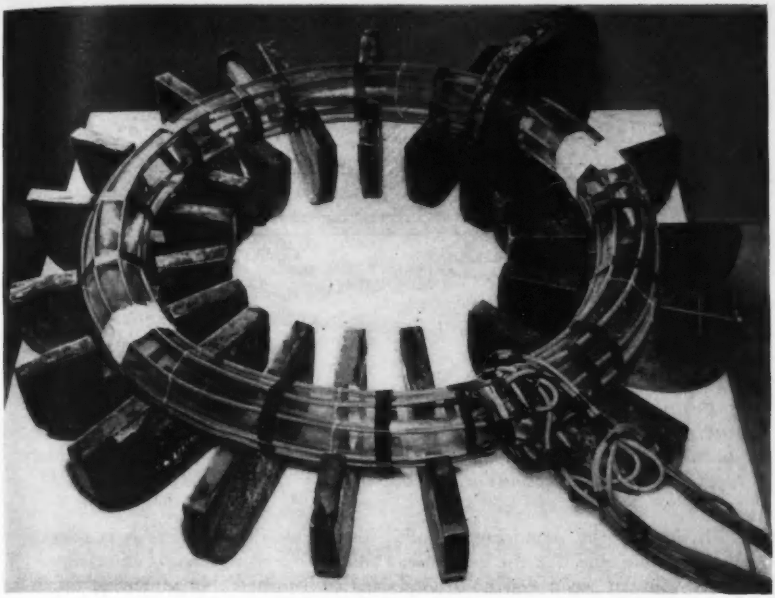
All in all, the controlled release of energy from fusion offers man for the first time the potentiality of an essentially unlimited source of energy. There is a multitude of problems to be met and solved before all this can become a reality.

We are still on the threshold of our research. If we have not yet had any sensational "break-throughs" of discovery, neither have we had any setbacks of a magnitude to dampen our enthusiasm, and the work continues — energetically.

Controlled Thermonuclear Devices

The kinds of devices being used to explore controlled fusion were described by Dr. Arthur E. Ruark, chief, controlled thermonuclear branch, AEC Division of Research, in the controlled fusion conference. These excerpts and the photographs accompanying give pertinent details.

➤ THE FIRST GADGET was called the "Perhapsatron." The working part is in the form of a tube or anchor ring or whatever word you want to use.



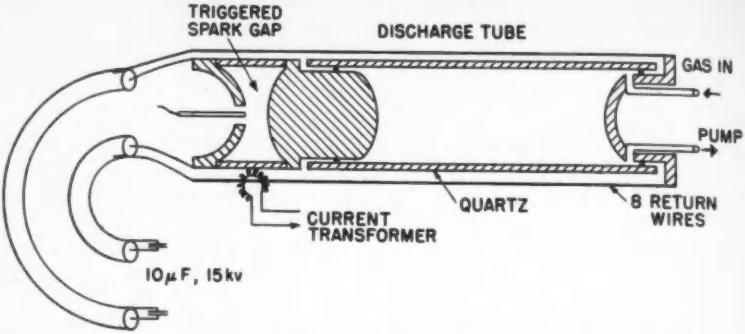
➤ PERHAPSATRON TUBE — *Primary windings and iron cores of the magnets used to heat gases for studies of the "pinch effect" are shown going around the Perhapsatron discharge tube, developed at Los Alamos Scientific Laboratory. Aim of the studies is to investigate the feasibility of controlling fusion reactions for peaceful purposes.*

The rest is a magnet for producing magnetic rings of force down through the middle of that ring. They are induced by this set of eight wires or so, which is the primary area of the transformer.

The iron is just there to help the magnetic lines of force to go down through the air in the middle of the ring. When that happens, it is the old Faraday and Joseph Henry induction effect.

There is an induced endless voltage around the ring. No beginning or ending. No electrodes or poles like on your automobile battery. So you can get a current around the ring. The ring might be something like 18 inches outside diameter. Such effects have been known for the last 50 years under the name of the electrode ring discharge. Many people worked on this as long ago as 1925. The current could be of the order of a low of 5,000, many times it would be 10,000, sometimes 50,000 amperes.

The primary of this transformer is not fed by a generator. It is fed by energy stored in a condenser. That is the little thing that does the work in actuality.



➤ Possibilities *of controlling H-bomb reactions for peaceful power were studied by AEC scientists at the Los Alamos Scientific Laboratory with apparatus such as that shown here schematically. This was called a Columbus-type discharge tube because it was one of early experiments.*

Physically, the condenser bank would be sizeable like the condenser banks you can see if you go around any unclassified accelerator project.

The current in the conductors was only a primary current to give a magnetic force down through the plane of this device which in turn induced another voltage, like the secondary voltage of a transformer, around the ring. That drives the current around the ring, and the magnetic field of the current itself, independent of all the other magnetic fields I mentioned, pinches the discharge together, and bang. When I said "bang" there, it is about a thousand or so times faster than that. This is a matter of microseconds or millionths of a second.

Next we want to see how things go in time. So if the tube is lying before us, we place a slit in front of it, and with the aid of a rotating mirror we draw out the light. This shows the light filling the whole tube at first. This shows where it is coming down to a diameter, not three-eighths of an inch here, but somewhat larger. Then it bounces and hits the wall, and here it comes in and out and in. It goes back and forth even as a pendulum goes back and forth.

It is a little hard to interpret these photographs in detail. There is not time. After a while it begins to wiggle. This is the great trouble, instability. The thing begins to break up into wiggles and finally as you see, it is dissipating itself in a most complicated way, and then the phenomenon is over. That is the death of the situation. You must get your thermonuclear power before that or you are not doing anything.

It breaks down in a matter of several microseconds in these experiments. Let us say up to 10 microseconds, though five might be a better average value. It just depends on conditions of the experiment.

There is a whole lot of visible radiation in the whole spectrum, right where the pinch occurs.

Now, we come on up to let us say 1954 or 1955. Experiments of this sort still go on. One of the early small outfits was called a Columbus. The first one was called the Perhapsatron, because of its tentative nature. Here they get away from the torus for reasons of experimental convenience. Heavier gases like krypton work well in these smaller experiments. The principle is the same, except we have it in a straight tube and the energy is dumped lengthwise through the tube. These experiments could not be expected to give power theoretically and in practice they do not.

The temperatures achieved would be of great interest to people who ought not to have it. High temperatures have been achieved, but not high enough.

In these experiments the absolute pressure of the gas in the tube might run from five microns up to 30 microns. It can be more. It would cover a range. Possibly 10 microns would be a good value. A micron is just about a thousandth of a millimeter of mercury.

The matter of the possibility of the straight conversion into electrical energy is an unclassified business.

Russian Fusion, 1956 Report

➤ RUSSIAN experiments aimed at learning whether thermonuclear reactions can be controlled for peaceful purposes were reported at a scientific meeting at Harwell, England, on April 25, 1956, by Dr. I. V. Kurchatov. He said it was among the more important problems of modern engineering science, attracting the extraordinary interest of physicists over the whole world.

Dr. Kurchatov pointed out it is well known that thermonuclear reactions can arise if the temperature of matter is sufficiently high for atomic nuclei to "surmount with appreciable probability the forces of the Coulomb (like charges repel) barrier during thermal collisions."

To achieve this, he said, very high temperatures are required. At such levels, deuterium is an almost totally ionized plasma (gas). The main problem, Dr. Kurchatov noted, is to exclude heat losses, which increase rapidly with temperature; still another is to overcome the enormous mechanical forces resulting from the increase of pressure with temperature. Even at 100,000 degrees, the pressure exceeds a million atmospheres.

Therefore, Dr. Kurchatov said, thermonuclear reactions can be induced only during a very short period of time in dense substances. One approach leads to stationary thermonuclear reactions. Another leads to the idea of utilizing an instantaneous temperature rise in transient processes of very brief duration.

With either approach, the problem arises of isolating the plasma heated to a high temperature from the walls of the vessel in which it is confined.

Dr. Kurchatov credited two Russians, Soviet Academicians Sakharov and Tamm, with being the first to point out the possibility of using a magnetic field for thermal insulation of the plasma, but scientists in other countries might disagree.

By passing sufficiently intense currents through the plasma, a magnetic field will be generated that will contract the plasma, the so-called "pinch" effect. An increase of plasma temperature should follow. However, a contracted plasma column detached from the walls can exist only as long as the current is building up, Dr. Kurchatov reported.

These theoretical ideas, he said, were followed by experimental investigation of intense pulsed discharges in a broad range of parameters characterizing the initial discharge conditions.

Discharges through hydrogen, deuterium, helium, argon, xenon and gas mixtures of various relative content were studied. The measurements were carried out at gas pressures ranging from five-thousandths of a millimeter of mercury to one atmosphere.

Most of the experiments, Dr. Kurchatov said, were performed with straight discharge tubes, and the length of the gap varied from several centimeters up to two meters and the diameter from five to 60 centimeters. The discharge was produced by a voltage of several tens of kilovolts, and the peak current varied from 100 kiloamperes up to 2,000,000 amperes, the rate of current build-up lying between ten billion and a million million amperes per second.

The highest instantaneous power released in the plasma was 40 million kilowatts. Banks of high-voltage condensers were used to produce the discharges, Dr. Kurchatov reported.

Oscillographs, ultra-high-speed moving picture cameras taking up to 2,000,000 frames per second, and photography aided by Ker cells were used to record results. They found that as many as three contraction and expansion cycles could occur, but never observed more than three.

Dr. Kurchatov concluded his report, as translated from the Russian: "The success of further work in this direction will greatly depend on the possibility of creating conditions under which the plasma column will experience multiple oscillations during build-up of the current without coming into contact with the walls. However, there are serious reasons to believe that this cannot be achieved.

"On appraising the various approaches to the problem of obtaining intense thermonuclear reactions we do not deem it possible to completely goal by using pulsed discharges. However, exclude further attempts to attain this ever, other possibilities must also be carefully considered. Especially interesting are those in which the idea of stationary process may be used."

Old people suffering from apathy, depression, fatigue, and mental decline, have started to enjoy life again through a "geriatric cocktail" of fruit juice and a new drug, L-Glutavite.

Molten glass may solve the problem of providing a lubricant for use in the hot forming process of titanium and other alloys.

National Meeting Hears Progress in Many Fields

American Chemical Society at Miami

The 131st national meeting of the American Chemical Society at Miami, Fla., in April, resulted in many reports of interest among the thousands of papers. Here are summaries of some of the developments made known at this meeting. Other articles in this issue also cover developments at this meeting.

Expect New Elements

➤ THE NEXT CHEMICAL element to be discovered probably will be found an atom at a time, believes Dr. Glenn T. Seaborg, Nobel Prize-winning chemist of the University of California. So precise are the techniques for detecting elements in that realm of chemistry where the next element will be discovered that a single atom could be positively identified.

Dr. Seaborg, who is professor of chemistry and associate director of the radiation laboratory, has had a part in the discovery of the last eight elements to be found, all known as transuranium elements. He received the Nobel Prize in 1951 for his nuclear research.

The transuranium elements, which are all radioactive and heavier than uranium, were produced by nuclear bombardment. Theories of atomic structure indicate that two more elements of this series remain to be discovered.

Dr. Seaborg said that further discovery of chemical elements awaits construction of the new heavy element accelerator, now nearing completion at Berkeley. But he predicted the behavior and properties of elements 102 and 103, each of which, he said, will "live" only about 30 minutes.

Dr. Seaborg was codiscoverer of element 94 — the important nuclear energy material, plutonium — in 1940. The latest of the series, number 101, Mendelevium, was identified in 1955. The latter element, which has an average life of only about half an hour, was first produced in quantities of only one to three atoms at a time, according to the speaker. Yet such a quantity, far too small to be weighed, could be detected with certainty by means of a combination of chemical and radiation-counting techniques, he explained.

The same procedures will aid in the discovery of elements 102 and 103, he said, and "single atoms of these elements" will be identified. This basic research is considered to be highly important in establishing the correctness of atomic theories and adding to the understanding of nuclear reactions.

A great deal already is known about the still undiscovered transuranium elements because they bear a chemical relationship to a series of elements known as the rare earths, numbers 57 through 71. Through the expected similarities to known materials performance of the unknown elements can be predicted.

The California scientists expect to produce the two remaining elements of the transuranium series by bombarding element 99, einsteinium, with such heavy elements as neon or nitrogen. Einsteinium exists in a relatively long-lived form and can be produced in weighable amounts. When the einsteinium is thus bombarded, Dr. Seaborg explained, only about once in a million times will the particles stick together to form a new element — the rest of the time, disintegration will occur through a fission reaction.

The "needle-in-a-haystack" hunt to find the new substance will depend on specialized chemical procedures — the same employed in identifying the more recently discovered elements. The search must be performed quickly, observed the chemist, because the newly-formed element will exist for only some 30 minutes.

The essentials of this chemical search, as described by Dr. Seaborg, follow: After bombardment, the material which is thought to contain some of the new element will be dissolved and mixed with an ion exchange resin. This resin will trade some of its electrically charged particles, or ions, for similarly charged particles in the bombarded material. Thus, any of the new element present will be trapped by the resin. The element will be recovered from the resin by placing the resin containing the element at the top of a glass tube containing more of the same resin and then pouring a wash solution through the resin. During this washing, the resin will release the various components of the bombarded material at different times and the new element will be isolated in this manner from other substances in the mixture. The new element will be detected by use of a radiation counter.

Dr. Seaborg said that the eventual identification of other new elements, beyond element 103, will be more difficult because they will not belong to the transuranium family and these detecting procedures will not do the job.

Radiation Speeds Fuel Burning

➤ ATOMIC RADIATION may be used to make fuels burn faster in aircraft or rocket engines, a University of Michigan chemical engineer suggested.

Prof. Stuart W. Churchill reported that beta particles emitted by a powerful bit of radioactive gold can increase the burning speed of fuel by 50%. The discovery means that smaller engines with radioactive "sources" might be used to do the job of bigger ones, since every pound saved in an aircraft part gives an additional saving of ten pounds elsewhere in the plane.

It also suggests that existing engines could be made more efficient or could operate at higher altitudes. Conceivably aircraft rockets or missiles could be equipped with radiation sources to whittle down engine weight in the space required for combustion.

Prof. Churchill emphasized the study was a preliminary one and that the results show an increase in burning speed of a given amount of fuel, not an increase in the power from it.

When the reaction was tested with radioactive materials less intense than the gold, rated at 10,000-curies, the flame's speed fell off rapidly to the

normal value, Prof. Churchill reported. The radiation caused certain parts of the fuel to be more reactive chemically and thus to burn faster.

The results with the 10,000-curie source were roughly the same for all the fuel air mixtures tried and at pressures ranging from those found between 30,000 and 50,000 feet above the earth's surface.

The studies were sponsored by the U. S. Air Force's Office of Scientific Research through the University of Michigan's Engineering Research Institute. The tests were conducted on a 24-hour basis over a period of three weeks.

New Process For Anti-Knock Gasoline

➤ A COMPLETELY new process for making tetraethyl lead, the chemical anti-knock additive used in gasoline to raise its octane count, reported by S. M. Blitzer of the Ethyl Corporation, means that tetraethyl lead can now be synthesized from a wide range of organometallic compounds in combination with many common lead compounds.

Probably the most significant discovery is that lead sulfide, lead oxide and lead dioxide react with organometallic compounds to form tetraethyl lead. The research team responsible for the discovery included Mr. Blitzer, T. H. Pearson, D. R. Carley, T. W. McKay, R. L. Ray, L. L. Sims and J. R. Zietz of the Ethyl Corporation.

Dyes Color Glass Cloth

➤ DYES FROM SAND have been found to be the first to be able to color glass, man's earliest known product from sand.

Silicone dyes, the first ever created, were described by Dr. D. L. Bailey of the Union Carbide and Carbon Corporation. The new dyes now make it possible for the first time to give dark and permanent colors to glass cloth.

"The new silicon compounds," Dr. Bailey said, "not only offer a novel approach to the synthesis of silicone dyes, textile finishing agents, and organic-silicon copolymers, but also are useful for modifying the properties of conventional types of silicone oils and resins."

Up until the creation of these "colors from sand," glass cloth had to be coated with another substance that could be dyed. And then at best, the color was semi-permanent and limited to pastel shades.

Plastics For Houses and Ships

➤ SUBSTITUTING ONE petroleum derivative for another petroleum derivative has resulted in new reinforced plastics that will withstand extremes of temperature and weather and keep their color and rigidity.

The new plastics are expected to find wide use in home construction and in the building of lightweight ships, Arthur H. Smith of the Rohm & Haas Company, Philadelphia, reported.

The new resin formulation is obtained by replacing part of the styrene, a petroleum derivative in conventional resins, with another petroleum derivative called methyl methacrylate, a widely used plastic.

Glass fibers are bound to the new plastic to reinforce it. James R. Lowry of Rohm & Haas was co-author of the report.

Chloroplasts Like
Tiny Photo Batteries

New Photosynthesis Theory

➤ A POSSIBLE explanation of an age-old mystery — how plants build sunlight into the food compounds that maintain life on earth — has been proposed.

Apparently plants have a mechanism similar to that of the Bell Telephone Laboratories photobattery, which is designed to capture sunlight and convert it into an electrical current.

Evidence for nature's "plant photobattery" is presented in a recent issue of the journal *Science* by Drs. Melvin Calvin and Power B. Sogo of the University of California, Berkeley.

They suggest, essentially, that bits of plant cells called chloroplasts act as "photobatteries," capturing sunlight and turning it into a kind of electrical current merging with the chemical reactions taking place in photosynthesis.

Dr. Calvin is credited with having charted, in more than a decade of work with radioactive carbon, the complex chemical steps by which plants convert water, carbon dioxide and sunlight into sugars, proteins, carbohydrates and other energy-bearing materials.

With this chemical phase of photosynthesis well on its way, the mechanism by which packets of energy from sunlight entered into the chemical process apparently has been the last major mystery in the process.

Recent studies by other scientists revealed that the chloroplasts, which contain the light-capturing green plant pigment, chlorophyll, have a well-ordered, quasi-crystalline structure, containing alternate layers of proteins, chlorophyll and fats. This arrangement was strikingly suggestive of the photobattery.

Dr. Calvin theorized that a packet of the sun's energy might strike an electron in the chlorophyll, bouncing an electron out and leaving a hole. The electron would then be conducted through the chloroplast, as in a photobattery, until it became attached to a carbon atom participating in the chemical process. Thus energy would be stored in the process.

Meanwhile, the theory suggested, the hole left in the chlorophyll molecule is filled with an electron stolen from an adjacent water molecule. This eventually splits the water molecule into its hydrogen and oxygen components, the oxygen going into the atmosphere and the hydrogen being used as a building material in the photosynthesis process.

Dr. Calvin suggested an experiment to test the idea, and it was first tried by three Washington University scientists, Drs. Barry Commoner, J. J. Heise and J. Townsend.

Essentially, the scientists send a radio-frequency wave through a chloroplast while a light is shining on it and also in the dark. They find part of the wave is absorbed in the light, indicating the presence of free electrons bounced out of the chlorophyll.

This supports the theory.

The version of Dr. Calvin's suggested experiment recently completed in Berkeley seems to be the most conclusive. Earlier experiments were conducted at room temperature, where free electrons might arise from chemical reactions in photosynthetic reactions.

Drs. Calvin and Sogo conducted their experiment at the low temperature of minus 140 degrees centigrade, or about 220 degrees below zero Fahrenheit. Since photosynthetic chemical reactions do not take place at this temperature at a measurable rate, the free electrons found to be present can be attributable only to the action of light flashed on the chloroplasts.

Free Radical Experiments

The Washington University team of scientists referred to by Dr. Calvin recently announced results of their experiments on both plant and animal life processes.

➤ A MOLECULAR bridge between the extremely speedy chemical steps that power life has been discovered in the unusual molecules known as free radicals.

Still poorly understood by science, the free radicals are shown here by a Washington University research team to:

1. Spark the unique reactions with which green plants store the sun's energy.

2. Act in the biochemical processes which release from food the energy required for life activities.

The discovery of the vital role of free radicals in normal life processes is expected to provide new attack methods on unsolved problems in biology and medicine. Damaging effects of atomic and other radiation and cancer production of some chemicals are believed to be due to the formation of free radicals in affected cells.

The Washington University demonstration of free radicals in normal cell processes, such as respiration and photosynthesis, will stimulate new efforts at understanding disease processes.

The team of biologists was directed by Dr. Barry Commoner, professor of botany, in collaboration with Dr. Richard E. Norberg, associate professor of physics, and Dr. Jonathan Townsend, assistant professor of physics. Working with Dr. Commoner were: Dr. Janet V. Passonneau, research associate in botany, Mrs. Barbara Sue Lippincott, graduate student in zoology, and John J. Heise, graduate student in botany.

Possible existence of free radicals in living cells was suggested, on theoretical grounds, about 25 years ago. Demonstration at Washington University that these elusive substances are active in living things was the culmination of seven years' work. This was based on new knowledge of the physics of the electron resulting from the discovery in 1945 by a Russian scientist, E. Zavoisky, of an absorption of radiofrequency energy by electrons.

As a result, a new instrument came into use, the electron spin resonance spectrometer, which employs radar energy in the presence of a strong electromagnet to reveal the presence of the unpaired electrons. Free radi-

cals contain unpaired electrons and are therefore capable of exerting a magnetic effect in the spectrometer. In ordinary molecules all electrons are paired up in a way which cancels their magnetism so that they are not detected by the spectrometer.

The results on biological free radicals were obtained with a new type of electron spin spectrometer, which can detect the extremely small amount of free radical that was expected. It was designed and constructed by Dr. Townsend.

The biologists extracted from pig heart muscle an enzyme which catalyzes the burning of food. This enzyme, and the chemical substances on which it acts, were placed in a glass tube inserted into the spectrometer. Experiments conducted in the past six months show that a few minutes after the enzyme begins to act, free radicals appear, then disappear as the reaction comes to completion. The spectrometer is so sensitive that in this experiment it revealed the presence of about one-billionth of an ounce of free radical. This result proves that enzymes removed from living cells form free radicals as they exert their catalytic effects. It confirms a theory first proposed in 1930 by the late Dr. Leonor Michaelis, biochemist at the Rockefeller Institute for Medical Research, New York.

During the summer of 1956 the investigators ground up spinach leaves in sugar solution to obtain from the broken spinach cells the tiny green particles called chloroplasts which contain most of the active agents of photosynthesis. These preparations were found at that time to contain a surprising amount of free radical. A strong light was arranged to illuminate the glass cell containing the chloroplasts in the spectrometer. When the light is turned on, the spectrometer shows a sudden jump in free radical content.

Detailed measurements recently analyzed by Dr. Norberg show that the chloroplasts contain two types of substances with unpaired electrons. One of these is a complex of the green substance of plants, chlorophyll, with protein. When this complex is illuminated the absorbed light releases unpaired electrons. These quickly disappear when the light is turned off. If the light is kept on, the unpaired electrons generated in the chlorophyll complex are passed on to a second free radical which in turn gives up the electron to enzymes that carry out the photosynthetic chemistry. Thus the investigators demonstrated for the first time the occurrence of a free radical chain reaction in photosynthesis.

This result agrees with predictions in 1941 made by Dr. Albert Szent-Gyorgyi, Nobel Laureate in medicine in 1937, that photosynthesis is a result of the flow of unpaired electrons in the chloroplast.

The Washington University team reported the first evidence of unpaired electrons in illuminated chloroplasts last October.

Living cells of the microscopic plant, Chlorella, were examined in the electron spin resonance spectrometer. The instrument showed the presence of a free radical apparently identical with the free radical found last summer in the spinach chloroplasts. When the light is turned on the amount of this free radical in liv-

ing Chlorella cells increases abruptly. When the cells are again darkened, the amount decreases. This represents the first proof that free radicals are formed in the activity of a living cell.

Photosynthesis As Old As Life

➤ A NEW THEORY of the origin of life on earth supposes that the ability to use the sunshine's energy arose almost in the beginning.

This speculation was proposed by Dr. Sam Granick, Rockefeller Institute for Medical Research plant physiologist, in a conference on spontaneous generation held recently by the New York Academy of Sciences and the American Association for the Advancement of Science.

It means that photosynthesis could have happened earlier in the rise of life on our globe than anyone has yet dared to suggest.

In the past the general ideas were that only after life had developed to a rather complex state did photosynthesis occur.

Dr. Granick supposes in his guess as to life's beginnings that there was a primordial mechanism that started off life by having some kind of energy supply that would act upon a mineral as a primitive energy unit. This would be a mineral that would operate in an oxygenless atmosphere with water, and with sunlight as the energy input.

A dark mineral, like magnetite, a form of iron ore, would absorb sunlight and have the ability to decompose water. It would be a photocatalyst and would develop organic materials. Life would begin in this high concentration of materials, through use of the sun energy.

Dr. Granick pointed out that many of the enzymes of the body today are known to have metal atoms as the focal point of their activities and he compares them with inorganic metal ions and finds they have similar properties. The metal atoms have the capacity of concentrating around themselves some material, bringing about reactions and forming protoplasm. This kind of reaction is being studied in laboratories.

Pure magnetite, which he believes could have been the energy unit, has properties related to the solar batteries that have been invented recently, Dr. Granick explained.

Lightning's electric discharges could have synthesized organic compounds out of simple materials in the oceans early in the earth's history to give ingredients for living organisms, Dr. Stanley L. Miller, biochemist of Columbia University's College of Physicians and Surgeons, told the spontaneous generation conference.

Dr. Miller sparked mixtures of gases for a week and made nine amino acids of which glycine, alanine, aspartic and glutamic acids occur in proteins. Glycolic, lactic, formic, acetic and propionic acids were also identified.

Such compounds were formed when the earth was young, he believes. They were carried down by the rains and reacted in the ocean to give amino acids and other complex compounds.

While this synthesis of amino acids is not the synthesis of life, Dr. Miller suggested that it is a step toward understanding how living matter may have arisen on the earth.

Wedding Between Two Sciences To Understand Human Complexities

Chemical Anthropology

by Dr. Roger J. Williams
Director, Biochemical Institute, University of Texas
President, American Chemical Society
A Summary of the Sigma Xi National Lecture being delivered during April and May

➤ There has always been, on the part of thinking people, an interest in the complexities of human nature. This interest continues in our more scientific age but we have been relatively ineffective in finding out what we can do about it. Today there is no more pressing problem than the one which Clement Attlee referred to when he said "since wars begin in the minds of men, it is in the minds of men that the defenses of peace must be constructed."

Historically many scientific as well as technological advances have resulted from the wedding of two different disciplines. Borderlines between the sciences are often the most productive areas of all.

In keeping with this idea, I propose a wedding between the two disciplines, chemistry and anthropology. I suggest that chemistry will make brand new contributions in this most intriguing area and that the "sciences of man" which has often been either in an ivory tower or else shaky as to its fundamentals will be tremendously enriched and strengthened by the insights which chemistry can bring.

When and if "the man in the street" hears about anthropology, he is likely to think of distant, ancient or prehistoric tribes. This emphasis is perhaps inevitable for social anthropologists who are interested in the development of cultures and who necessarily desire to start with primitive beginnings. Physical anthropology does not necessarily dwell upon the ancient or prehistoric, though ancient skulls and skeletons have historically been highly intriguing.

I predict that when chemical anthropology has a chance to develop, it will center its interest to a high degree upon men here-and-now, and upon a here-and-now science of man. Neither physical anthropology nor social anthropology will be superseded but something new will be added. This will enrich every facet of the entire field.

I would not suggest that up to now the science of chemistry has been completely neglected by everyone interested in the science of man. This, of course, is not the case. What I am proposing, however, is that competent chemists put their concentrated research effort into unravelling the secrets which lie hidden in human beings, secret factors that are important in making them behave as they do.

While I would not be restrictive as to its scope, I believe chemical anthropology will be particularly valuable in

making it possible to understand not why people all behave alike but why they do not.

The scientific study of human behavior which encompasses the vast and active area of psychology, has tended to follow a pattern which I believe will change with the ascendency of chemical anthropology. Science has, in this area like others, been looking for simple universal laws which will apply to all humanity. This is not exactly a modest quest when we consider how complex human beings are.

There are, of course, certain broad principles such as the idea of stimulus and response and learned or conditioned reflexes which doubtless are operative in human behavior. While chemical research should increase our insight into how these factors operate, this is not the area in which I think immediate advance can be expected.

Already in fact, before there is a single volume which encompasses the area or a single journal devoted to publishing its findings, chemical anthropology has shown the way to a revolutionary insight into human nature.

This basic insight may be expressed in a few words: Human beings — all of them — possess individuality to such a high degree that this must be taken into account before human nature can possibly make sense. Since we have considered human beings as products of mass production and have attempted to gain an understanding of their behavior on a wholesale basis, it is no wonder that our accumulated scientific knowledge about human behavior, that is, knowledge about which there is general agreement, is scanty and rudimentary.

The evidence upon which my statement about the universal possession of a high degree of individuality is based, is both chemical and anatomical. Since it is basic and easier to grasp, let us consider the anatomical evidence first, though in my own experience the chemical evidence came first and the anatomical later.

Our bodies are by no means built alike; 3-to-5-fold or larger variations in the sizes of our internal organs are common. Size, position and attachments of muscles vary from individual to individual to such an extent that 11 diagrams are necessary to show the attachments of the extensor muscle of the index finger alone. Our hearts vary greatly in structure so that in some cases it would be difficult to believe that they came from the same species. In normal young men, the pumping capacities vary over a more than 3-fold range. The circulatory systems in each of us has a distinctive pattern; for example, there are sometimes two, sometimes three and sometimes four arteries arising from the aorta as it leaves the heart. Our nerve patterns are as different as the river systems on different continents. Our brains differ enormously in structure, and are unlike in number, size and arrangement of neurons as well as in grosser features.

Biochemically we find that 5-to-10-fold variations in endocrine gland activities are common, and that even greater variations in enzyme activities of the blood (insofar as these have been investigated) are at every hand. Samples of blood from differ-

ent individuals vary not only with respect to blood types but with respect to other constituents. Each individual has a distinctive pattern of blood composition. Urine compositions are distinctive (this was one of the earliest findings) in that each individual exhibits a different pattern of composition. Enormous differences exist in taste thresholds for various substances and in the action of various drugs. There is ample evidence to indicate that each individual has his own pattern of nutritional needs.

Two normal young men may have over-all basal metabolisms which are about the same, but clear evidence shows that when the details of metabolism are examined, they exhibit patterns which are highly different.

All of these facts have tremendous implications for inter-human sympathy and understanding, for marriage and family relations, for education, for athletics and recreations, for criminology, for prevention of mental disease, for the prevention and cure of numerous diseases of obscure etiology. These implications cannot be discussed in a short space.

One of the specific problems which has been attacked on the basis of these concepts is alcoholism. Though there are psychological factors involved, we are certain that in keeping with the facts of biochemical individuality, alcohol "does things" to some individuals that it does not do to others, and that the differences have a nutritional basis that has been discovered in some cases and can be discovered in others. Without recognizing differences in the body chemistry of individuals, this disease is certain to remain in the class of "incurable." Our studies indicate that it can be cured and what is perhaps more important, it can be prevented. Acceptance of the idea of the importance of individuality by many investigators is essential to progress in this and many other areas.

It should be pointed out that in making a proposal with respect to "chemical anthropology," I am not concerned with the name but with the idea behind it. Whether what I have been talking about is called "chemical anthropology" makes little difference. Actually a well developed science of man must encompass much that is known in the field of biology, including genetics, much that is in biochemistry and presumably all that is now covered by the designations psychology, anthropology and sociology.

Citrus Chemicals Don't Help Colds

➤ CITRUS peel chemicals, called bioflavonoids, do not, contrary to a recent report, prevent or shorten the course of common colds or make the sufferer more comfortable, five doctors report on the basis of two separate studies.

These latest, unfavorable reports, in a recent issue of the *Journal* of the American Medical Association, are from Drs. Warren L. Franz and Henry L. Heyl of Dartmouth Medical School and the Hitchcock Foundation, Hanover, N. H., and Drs. Harry E. Tebrock, New York City, Joseph J. Arminio, Ossining, N. Y., and John Howard Johnston, West Hartford, Conn.

Six Gold-Plated Spheres Are Forerunners of Actual Satellites

Gold-Plated Moons

➤ SIX GOLD-PLATED magnesium spheres, forerunners of the actual satellites to be launched during the International Geophysical Year, have been received by the Naval Research Laboratory at Washington, D. C.

Final outer coatings of the spheres are now being applied at the Research and Development Laboratories of the Army Corps of Engineers at Fort Belvoir, Va. The shiny globes, 20 inches in diameter with a skin 0.032 inch thick, were built by Brooks and Perkins, Inc., Detroit, under Navy contract.

Four coatings go over the gold plating: an adhesive layer of chromium, a separating layer of silicon monoxide, next a layer of highly reflecting aluminum, and a thick, final layer of silicon monoxide. The outer coat is to absorb infrared rays and emit heat, thus protecting the aluminum.

The coating is done in vacuum vats in which the vaporized coating material is deposited on the spheres by condensation. The finished globes will be given a mirror polish.

When the satellite gets into its orbit, it will be about as visible optically as a shiny golf ball traveling at the speed of sound at 60,000 feet, the Naval Research Laboratory reports. Therefore, scientists will try to track it initially by radio, using a small 10 to 50 milliwatt transmitter called the Minitrack. In case the radio fails, however, teams of volunteer observers will attempt to spot it with especially-designed optical equipment.

To detect the weak radio signal, only a millionth as strong as a standard radio broadcast, special receivers are being built. One of these is now in operation at NRL's satellite tracking station, Blossom Point, Md. Eleven more are being built by Bendix Aviation Corporation.

The position of the earth-circling satellite will be computed by measuring the minute differences in time required for the radio signal to reach each one of several ground antennas, spaced as much as 500 feet apart.

A computer to determine the exact moment when the third stage of the launching vehicle will be fired, injecting the satellite into its orbit, has been completed and tested by Air Associates, Inc., under a subcontract with the Glenn L. Martin Company. It is known as a "coasting time computer," the Office of Naval Research reports in a recent issue of *Research Reviews*.

The first stage of the three-stage rocket that will fire the satellite into space will use a special grade of kerosene called Shell UMF Grade B as fuel. It is produced by Shell Oil Company through close control of refining operations to obtain the particular characteristics needed for rocket fuel.

Plastic from Lignin, Cotton Molecule Fireproofed, Cellulose Made Outside Cell

New Cellulose Developments

At the Miami meeting of the American Chemical Society advances in using wood and cotton utilization were announced. The reports are summarized in this article.

Synthetic Fiber From Lignin

➤ A NEW SYNTHETIC textile plastic has been made from the paper industry's most troublesome waste, lignin. This promises to add a new fiber to those available to industry as well as utilize a voluminous and cheap by-product of paper pulp and cellulose production.

A report by two chemists, Dr. Louis H. Bock and James A. Anderson of Rayonier, Inc., Shelton, Wash., told of this new chemical achievement.

The new synthetic which chemically is a polyester is made from vanillin, the synthetic vanilla, which is made from lignin. Nearly a third of the wood used in making paper is lignin. This material may be thought of as the glue or cement in which the cellulose of the wood is embedded. Lignin is so plentiful that it is actually burned in paper mill boilers.

To make the new fiber, vanillin is converted into protocatechuic acid from which the new unnamed polyester material is made.

Protocatechuic acid is also obtainable from the bark and needles of the western hemlock and this may allow the utilization also for fiber production of the portions of the tree not useful for lumber or paper.

Molecule Remodeled For Fireproof Cotton

➤ NEW FIREPROOF textiles have been made by remodeling the chemical structure of cotton and viscose rayon by introducing changes in some of the original parts of the molecules.

Robert F. Schwenker Jr. of the Textile Research Institute, Princeton, N. J., and Dr. Eugene Pacsu, Princeton organic chemistry professor, told how built-in flame resistance and smolder-proof properties had been obtained.

Most fire-retardant textiles have a chemical coating to combat burning. The new process follows a mechanistic theory for the decomposition of cellulose at elevated temperatures. Experiment and theory indicated that a suitable chemical modification (of the primary alcohol group at the 6 carbon of the glucose anhydride unit) of the cellulose chain should impart flame and glow resistance. It was also possible to introduce elements, including bromine and iodine, to suppress flaming and afterglow as well as alter the reaction path. In the cotton and rayon fibers this was done without impairing essentially the textile properties of the original materials.

The chemists expect that the same methods can be used to produce flame-resistant wood pulp products, such as fiberboard and insulation.

Cellulose derivatives that show a high degree of flame resistance were also reported by Dr. Elias Klein and

James E. Snowden of the Southern Regional Research Laboratory, New Orleans, La. The new textile fibers were made by replacement of hydroxyl groups in the cellulose of cotton. They are expected to have practical uses.

Mildewproof and rotproof cotton suitable for use in awnings, tenting, tropical clothing, ironing board covers and sandbags are promised for the future by the process known as cyanoethylation now used on a small scale. Acrylonitrile, produced from natural gas and used in production of the synthetic Orlon and Acrilan, is joined with cotton in this process. A method of reducing costs of cyanoethylation was reported by Norbert M. Bikales of the American Cyanamid Co., New York.

Cellulose Made Outside Living Cell

➤ CELLULOSE, hitherto a monopoly of living cells, has been produced for the first time in the laboratory in a cell-free enzyme system, Prof. Glenn A. Greathouse of the University of Florida reported.

Small, transparent membranes of cellulose, tagged with radioactive atoms, were made with the aid of enzymes, naturally occurring agents that promote chemical processes in all living things. A complete synthesis or artificial production of the plentiful woody material was not claimed.

Prof. Greathouse began with glucose that had been labeled with radioactive carbon in a particular part of its molecule. After the cellulose had been made and then broken down into glucose again, 96.7% of the radioactive carbon was still in the same position. This was strong evidence that the enzymes built the glucose into the cellulose structure directly instead of breaking them down into simpler materials and rebuilding them into cellulose.

Prof. Greathouse's research is expected to aid in explaining how cellulose is made by trees and other plants.

Bee Sting Venom Antibody

➤ THE SEARCH for immunity against bee stings is still far from over, but researchers at the University of Wurzburg, Germany, report finding that two components of bee venom cause antibody formation in rabbits.

Earlier studies have shown that bee venom is composed of two groups of ingredients, Ernst Haberman and Mahmoud M. A. El Karemi report in a recent issue of the British scientific journal *Nature*.

One group, the so-called "fraction I" contains the highly poisonous ingredients, they report. The other group, "fraction II" contains the enzymes phospholipase A and hyaluronidase.

Rabbits given repeated doses of the two enzymes built up immunity to them by forming antihyaluronidase and antiphospholipase in their body, the researchers found.

However, the highly poisonous "fraction I" caused no apparent production of antibodies, and the body fluid from immunized rabbits was helpless against the effects of the toxin in white mice or on human red blood cells, they reported.

Train "Modern Engineers" Not Nuclear Specialists

Nuclear Engineering

by W. KENNETH DAVIS, *Director, Division of Reactor Development, U. S. Atomic Energy Commission*

(Excerpts from remarks presented before the Nuclear Engineering Division of the American Institute of Chemical Engineers, Philadelphia, Pa.)

➤ WHAT IS THE definition or description of a "nuclear engineer"? Is there really such a fellow? What does a nuclear engineer do? What should be the education and training for nuclear engineering? What is the need for "nuclear engineers"?

I do not believe that there is any more need for a new engineering field called "nuclear engineering" than there was for a new area called "chemical engineering." You may argue that history has demonstrated the need in the case of chemical engineering. The same history also shows, however, that the older fields of engineering were not willing or able to adapt themselves to new concepts and requirements and that it was thus necessary for a new field to be created which otherwise might never have been needed.

If the mechanical engineers had been willing to think about other fluids than air, water, and steam; if the materials people had been able to expand their horizons past steel and wood; if the chemists and physicists had been willing to consider practical thermodynamics, heat and mass transfer processes, kinetics; and if there had been a mechanism for reorienting the educational system in terms of the then new requirements I do not believe that there would have ever arisen a separate field of chemical engineering.

Nuclear engineering today stands in approximately the same relation to older fields of engineering as chemical engineering did 40 years ago. The situation is perhaps even more serious because we are less able to afford the luxury of starting a new field. Engineering has already been proliferated and fragmented to an untenable degree.

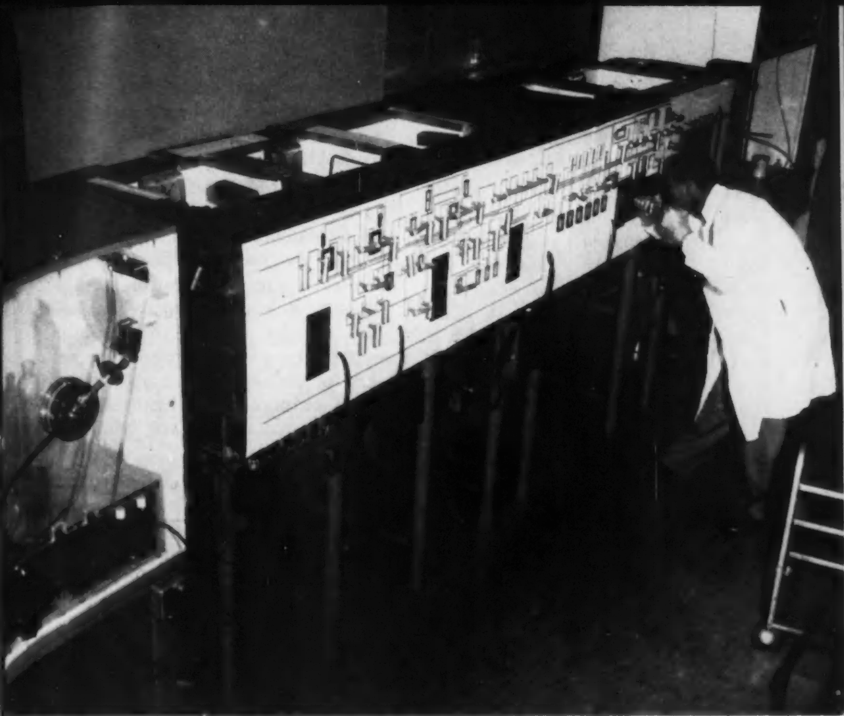
Perhaps a new field of "nuclear engineering" is really required. If it is, then let us face up to it. However, let's be sure and not just jump into it because it is glamorous or offers the easiest way out.

What Is Engineering?

Perhaps one should inquire first as to the definition of an engineer. I have always liked the qualitative definition ascribed to Professor W. K. Lewis:

"An engineer is a fellow who can do for one dollar what any damned fool can do for two dollars."

At the other end of the scale of definitions is the rather precise but useful one provided by Dean M. P.



➤ PLUTONIUM *is separated from uranium in this small-size plant that duplicates most of the facilities of the actual plant at the Hanford atomic plant, Richland, Wash. The prototype plant, despite its small size, weighs* 30,000 *pounds because of the radiation-absorbing lead brick. General Electric engineers built it so that the process steps are controlled from the outside.*

O'Brien of the University of California.

"The activity characteristic of professional engineering is the analysis, planning, or design of machines, circuits, structures, or processes, or combinations of these elements into systems and the prediction of performance and cost. Professional engineers are persons qualified to engage in this activity by virtue of their education, experience, and demonstrated judgment."

While Dean O'Brien's definition seems to me to be a little deficient on both the development and operating sides, it is a useful one for crystallizing one's thoughts.

Atomic Energy as an Industry

One illusion about nuclear energy is that it is a unique field of knowledge of some definable dimensions. It is truly more of an industry than a separate field. While it does not yet have all the characteristics of such established industries as the oil industry, the chemical industry, or the

automotive industry, it has some of them and will surely develop into a new industry or perhaps even into several related industries.

There is, however, a uniqueness about the infant industry. In most of its aspects it makes unusual requirements. It needs exotic materials and metals. It needs unusual degrees of purity in these materials. It needs vast amounts of commodities such as electric power. In some cases it needs vast amounts of otherwise unused land. Even the requirements for technical personnel seem to be, to some extent, unique. However, it is easy to get carried away by this line of thought. A good part of my argument tonight is to discuss these unique features and their implications. Everything seems to be unusual about the atomic energy industry.

New Engineering Requirements

We are dealing with some entirely new engineering materials. In nuclear reactors, new materials are needed which will have the requisite strength and corrosion resistance under the intended operating temperatures and pressures but which will not wastefully consume the valuable neutrons as many conventional materials do. A whole new technology of zirconium and its alloys has been developed to try to meet this requirement in water cooled reactors.

It is also necessary to provide new materials to carry out some new functions. The slowing down or moderation of neutrons in a reactor is a good example. Here materials such as graphite, beryllium, heavy water, and others have had to be developed to a point of practical use.

Another function is that of control and here it has neutron absorbing materials but also of reliable mechanical actuating systems and electrical control systems.

New coolants have been explored and a considerable technology evolved to meet the special requirements of reactors where low neutron absorption, low induced radioactivity, good heat transfer characteristics, high temperature, and low pressure are but a few of the desirable characteristics. Liquid sodium, liquid bismuth, and special hydrocarbons are some of these new coolants.

The examples could be extended. A host of new materials must be explored about which very little is known or was known only a decade ago.

Not only must new materials be developed but the properties and behavior of supposedly well known materials must be found under new conditions of use. One of the principal new conditions is that of exposure to radiation and neutron bombardment. There are also new conditions of temperature, pressure, and environment.

It has been amazing as well as disappointing how the field of knowledge about such materials as stainless steel, water and aluminum has been circumscribed by the areas of conventional interest — with little or no knowledge available beyond these limits.

There must also be wide investigations of the methods of producing and fabricating the materials, since they are of little value if they cannot be made into the desired form and if this cannot be done cheaply.

The task of carrying out these investigations is of monumental proportions if the traditional methods of doing such work are followed. We do not have many alternative methods today. As a consequence we find our programs limited by excruciatingly slow progress.

Need for Basic Knowledge

What is the solution? One is time — and this will be a good part of the answer provided the proper effort is made. Another answer is that of obtaining a better understanding of the basic theory of materials and their behavior under various conditions. The empirical approach which has served us so long seems inadequate to the needs of modern technology.

Sadly, we do not really understand much about materials. The triumphs of understanding such as culminated in the transistor are still few and far between. The development of theories of materials and their application to practical problems must be ranked as one of the most important engineering problems of the next decade.

There are additional factors beyond merely new applications which stress the importance of a real knowledge of the theory of materials.

One of these factors is that in modern engineering we frequently encounter situations where the time-honored approach of depending on design safety factors simply will not work. The covering up of lack of knowledge by use of safety factors must come to an end. Safety factors are also used to cover variations of a statistical nature in the properties of materials, and this margin must also be reduced. We must have much closer control over quality and new methods of establishing quality by non-destructive testing.

Consider a zirconium tube in a reactor where the tube contains the fuel material and a coolant under high pressure. If we are unsure about the physical properties of zirconium at the design conditions (and after several years of irradiation) we might consider making the wall of the tube much thicker to cover the possible corrosion, the effect of radiation in possibly weakening the tube, and the possibility that the tube material might be weaker than average. The only trouble is that this won't work. Making the tube thicker will increase the stresses due to irradiation. Also it may increase the loss of neutrons to a point where the reactor may be significantly less economic or perhaps will not work as designed. The only solution is a more complete knowledge of the expected behavior of the tube material and control of its quality so that one can depend on each individual tube, not on the statistical average.

Further, failure of components in nuclear power plants are far more serious than in conventional types of plants. In a piece of equipment such as a nuclear reactor repairs are likely to be relatively expensive and difficult. The loss of time may also be proportionately more important because of the higher capital costs. In extreme cases there may even be some hazard to the machine and to its operators.

The Modern Engineer

What do these circumstances mean for engineers? They mean that the engineer must be much better versed in such basic fields as physics, chemistry, and mathematics, and that, in

addition, he must depend on and work much more closely with experts in these fields. They also place a much greater emphasis on development and engineering research than ever before, which in turn demands people with not only a good fundamental training in engineering and the fundamental sciences, but also imagination and initiative to an uncommon degree. Thus, there are a number of questions raised not only with respect to engineering education but also to organization and emphasis.

Are these problems unique to the nuclear energy field? It is clear that they are not. Similar problems and requirements could be cited from many of the advanced fields of engineering such as aircraft, missiles and electronics. These problems encompass virtually every accepted field of engineering, chemical, mechanical, electrical, civil, to name only the more common ones.

Not only this, the modern engineer must have some understanding of these many fields of engineering since his work must of necessity cut across many fields in modern technology. He can afford to be neither superficial in his thinking nor an expert in only one narrow area.

The modern engineer is more closely related to the scientist than the engineer of the past. The scientist seeks to advance the frontiers of theoretical and empirical knowledge, the engineer seeks to apply this knowledge to practical use. The principal difference which remains today is largely one of intent and that even here there is only an artificial difference. The problems of application in modern engineering are often as complex, if not more so, than those of research. When the economic requirement that there be optimum use of men and resources is added, the modern engineer must be a man of truly unusual capabilities.

I submit that neither logic or practical evidence supports the idea that there is, in fact, a distinguishable field of "nuclear engineering."

Education for Nuclear Industry

What about specialized engineering education to prepare engineers for work in the nuclear industry? First, consider the present situation as it relates to engineering students:

(a) The preparation of freshmen students for technical studies has deteriorated over past decades — not so badly as some would have us believe — but seriously enough.

(b) The increased mobility of our population and the requirements for military service make it very difficult to predict just what field of work a young man (or woman) will actually enter.

(c) The horizons of every field of science and engineering have widened to a point where even the specialist has great difficulty keeping abreast of developments in his field.

(d) There is an awareness, in some cases even an over-emphasis, of the necessity for a truly educated man to be disciplined in the liberal arts and to be able to communicate effectively with his fellow man.

(e) The complexities and advancement of the scientific and engineering fields have placed a great premium on logical thought, imagination, and proficiency with such tools as mathematics.

My own observation based on both AEC and industrial experience is that neither special education nor long specialized experience are needed to do an effective job in research and development in the atomic energy field. These are helpful, in many cases, but not a necessity. The principal requirements observed are a sound background in the basic work of science and engineering, initiative, and imagination.

The most appalling bar that I have encountered to successfully interesting engineers and even scientists in work in the nuclear energy field is the feeling on the part of many, far too many, of them that nuclear energy is a foreign and mysterious field which they could never understand and in which they could never find their way. It is almost as though they expected whole new sets of physical laws and mathematical theorems to be necessary and true in this new "wonderland."

This is a serious danger, particularly since it affects a substantial number of the university professors who will have to provide basic education if a wholly separate field of nuclear engineering is to be avoided.

It was under quite similar circumstances that chemical engineering was born 40 years ago.

In nuclear energy, there are new concepts; there are more complex systems to be analyzed and explored. There is, indeed, a new "language" which must be learned and understood, but these are things that intrigue and challenge the true engineer or scientist — they do not scare him and cause him to seek refuge in what he knows he knows.

Dangers of Specialization

There might be some limited virtue in training engineers to carry out specific tasks in the nuclear energy industry if one were sure of three things: (1) that the engineers so trained would be working in this area; (2) that the techniques and requirements in this area would not change substantially with time; and (3) that the faculty required would have intimate knowledge and experience in the field.

Under such circumstances, a narrow training might provide engineers who would be of value even if they did not have the qualifications of the "modern engineers" which I have discussed.

What are the prospects for such an approach — an expedient at best?

It is doubtful that most of the engineers trained would find themselves actually employed in the activities which their specialized training especially fitted them for.

Are the techniques of a specialized field likely to remain stable enough to be a profitable area of training?

I do not consider myself an old man (despite the opinion of my children) yet in the 15 years since I was released upon the unsuspecting world of engineering I have seen nearly everything that I learned which was based on engineering practice superseded. Whole new areas of science and engineering have arisen. Not the least of these is nuclear energy technology.

Changes in nuclear technology are absolutely certain and are, in fact, taking place at an increasing rate. The rate is really limited by the abil-

ity of our scientists and engineers to accept their own creativity.

The practical difficulty of obtaining a faculty to train students in advanced enginering applications of nuclear technology, transitory as such training might be, is actually much worse than the problem of obtaining a faculty to teach students in sciences and basic engineering — and to teach them to think.

All in all, I believe we have a better chance of interesting in an academic career the person who is himself interested in training the engineer to think, than we have in interesting the man who is himself intrigued with the specific application.

Paying the Professors

Of course, one of the facts of life is that except for some unusual bargains you usually get what you pay for. It is fortunate that American universities are still getting a lot of unusual bargains in the way of engineering professors. But it is deplorable that the salary levels in our universities are so low that it is difficult to hold top-flight men on the professional staffs and almost impossible to take them away from industry and put their talents to work training our young people. I am not sure that the responsibility rests on the universities themselves. I think that the responsibility rests on all of us and that it is the duty of every American citizen to do something about the social and economic factors that figure in this equation.

The average B. S. in engineering or science today gets as much money as full professors in some universities. Some of the B. S. graduates get more. The doctor's degree engineer gets more money than full professors in all except a handful of universities. The universities often pay higher salaries to physicians and lawyers — seldom to engineers or scientists.

Sure, there are advantages to university life. There are lots of scientists and engineers who have no desire to be wealthy. But on the other hand most of us are interested in a reasonable standard of living as professional people. This is almost impossible to achieve on present university salaries in engineering and science. There are lots of dedicated people who are waiting this out in the hope that it will change — and there is an increasing number who are simply there because it is the best job they can find.

It is my belief that the relative pay of scientists and engineers will increase with time as the only method of securing the numbers needed by our economy — an economy of increasing technology. I can also state with a perfectly clear conscience that I am heartily in favor of this.

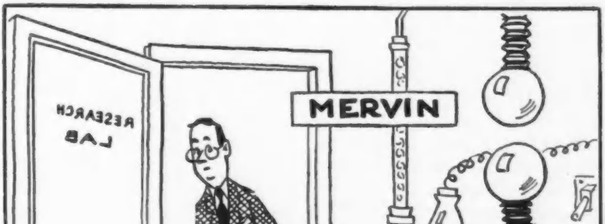
The universities and, of course, the high schools, too, should press their efforts to remedy the situation; but all of us, as taxpayers and supporters of institutions of learning, should begin to face up to the facts and help correct the obvious shortcomings of our educational system.

Need for Fundamentals

In conclusion, let me state again that there is a need for "modern engineers" who have new characteristics, unknown in the conventional engineers of years gone by. They must have a much better education in the

sciences and in engineering fundamentals and must be able to deal with broad and complex problems encountered not only in the nuclear industry but in many other phases of modern technology, not only as individuals but as members of a team.

The importance of really adequate education in the fundamentals of science and engineering, the importance of initiative and imagination, and the importance of knowing how to think is rapidly increasing in this nuclear age. We must accept this challenge to our progress. I submit that the problem is in the needs of what I have called "modern engineering" not in the establishment of new and separate engineering disciplines such as "nuclear engineering."



➤ *"I think he smashed an atom and lost one of the pieces!"*

For The Home Lab

The Story of Calcium

II. The Compounds

by Burton L. Hawk

The compounds of calcium are far more important than the element itself. While the metal has been put to limited use only in recent years, the compounds have been used since the dawn of civilization.

Lime

Calcium combines with oxygen to form the famous oxide familiar to everyone as lime. It is made by roasting limestone. Pick up a small piece of limestone or a marble chip with a long-handled tongs and hold it firmly in the hottest portion (near the tip) of the Bunsen burner flame. Continue heating the mineral until it glows red for about 5 or 10 minutes. Then drop it into a mortar. When cool, crush the lump with the pestle. It should crumble to a dry powder rather easily. If it does not, it must be heated again.

Transfer the powdered lime you have just prepared to a watch glass and allow a drop or two of water to fall upon it. The action should be quite vigorous and considerable heat is generated. Carefully feel the bottom of the watch glass and notice how warm it becomes. Continue to add water, drop by drop, as long as the powder absorbs it. The product is known as *slaked* lime, or *hydrated* lime. This is the type usually supplied commercially for fertilizer, whitewash, etc.

Whitewash. To make whitewash simply grind hydrated lime with sufficient water for proper consistency. In quantity, use about 5 lbs. of lime to each gallon of water. Whitewash was once a very popular coating for cellars, cinder blocks and fences (remember Tom Sawyer?), but it has been largely replaced by other modern paints which do a better job.

Mortar. Mix in a mortar 3 parts of fine clean sand with one part of hydrated lime. To make the mortar in your mortar, just add water.

Patching plaster. Patching plaster consists of a mixture of 1 part plaster of paris (see below) with 5 parts of lime.

Actually, hydrated lime is calcium hydroxide. This compound is only slightly soluble in water. Stir about a teaspoonful of hydrated lime in 500 cc. of water for a few minutes, then allow the solution to settle. Carefully pour off the clear liquid. This is a solution of calcium hydroxide, known as *limewater*. Save it for use in the following experiment.

Marble, Etc.

The carbonate of calcium is a most versatile compound. It is found widely in nature. The most common native forms are limestone and marble. The crystalline forms are calcite and aragonite. Iceland spar, Oriental alabaster, dog-tooth spar, onyx, stalacites,

stalagmites, chalk and marl are all forms of calcium carbonate. Pearls are calcium carbonate as well as coral, eggshells and the shells of sea animals. The finely powdered form is known as *precipitated chalk*, and also as *whiting*.

You can demonstrate the way the carbonate is formed from carbon dioxide by setting up a CO_2 generator and bubbling the gas through limewater. Place some marble chips in a large flask and cover them with about one-half inch of water. Insert a two-hole stopper in the flask containing a thistle tube in one hole and the outlet glass tubing through the other hole. Be sure the end of the thistle tube is immersed beneath the surface of the liquid in the flask. Immerse the end of the outlet tube beneath the surface of the limewater (prepared above) in another container. Add hydrochloric acid through the thistle tube. Carbon dioxide is generated and will bubble through the limewater. For a more interesting effect, add a drop of phenolphthalein solution to the limewater. It will turn pink. As the CO_2 bubbles through the solution the pink color will gradually disappear. If you continue bubbling the gas, the white precipitate of calcium carbonate will gradually settle out. If you continue the gas still longer the white precipitate will redissolve. (You will have to add more hydrochloric acid through the thistle tube from time to time). This happens because an excess of carbon dioxide forms calcium bicarbonate which is soluble in water. If this solution is then heated, the dioxide is driven off and the carbonate is again precipitated.

Putty. Common putty consists primarily of calcium carbonate ("whiting") and linseed oil. Simply mix the two ingredients thoroughly until you obtain the right consistency.

Gypsum

The mineral *gypsum* is a form of calcium sulfate found in nature. The crystalline varieties are called alabaster, selanite and satin spar.

Plaster of paris. This compound is gypsum from which three fourths of its water of crystallization has been removed. To make it, simply heat the gypsum mineral to a temperature of 165 to 200 deg.

You can prepare synthetic calcium sulfate by reacting calcium hydroxide with dilute sulfuric acid or by adding a solution of sodium sulfate to a solution of calcium chloride.

And Others

Calcium chloride can be made by dissolving hydrated lime in dilute hydrochloric acid. The hexahydrate form is crystallized from this solution. When heated, it forms the monohydrate which is porous and very deliquescent. Place a small lump of this product in a dish and let it stand for a while. You will note the compound soon becomes wet with moisture absorbed from the atmosphere. For this reason calcium chloride makes an excellent drying agent for gases in the laboratory.

Calcium acetate is formed by the action of lime with acetic acid. Acetone can be prepared from it. Place a small quantity of the compound in a dry test tube. Carefully apply heat, trying not to scorch the powder. Smell cautiously at the mouth of the tube. Can you detect the odor of acetone?

Calcium nitrate is used as a fertilizer. *Calcium chlorate* is used to kill weeds. *Calcium bisulfite* is used in the manufacture of paper. *Calcium tungstate* is employed in the manufacture of luminous paint. *Calcium hypochlorite* is a popular bleaching agent. *Calcium fluoride* is an important raw material for the production of hydrofluoric acid and other fluorine compounds. The *phosphates of calcium* are used for fertilizers, as an ingredient of baking powders, in animal feed, in dentistry, and in the manufacture of glass. *Calcium sulfide* is used in luminous paints.

Equipment and Reagents Suggested for a Basic Home Lab

In answer to an inquiry from a reader, Burton L. Hawk, author of CHEMISTRY's "For the Home Lab" series, suggests what is needed to start a home chemical laboratory.

➤ IT IS VIRTUALLY impossible to obtain a completely equipped home laboratory in one initial purchase. As you progress in your experimenting you will develop a requirement for certain types of apparatus and reagents, depending on the phase of chemistry you wish to follow. Thus a complete lab will be the result of a gradual accumulation throughout the years.

Equipment

We will, however, give you our suggestions for a "basic" lab, which is the minimum equipment you will need:

1—Separatory Funnel
1—Medicine Dropper
2—Glass Stirring Rods
1—Spatula
24—Test Tubes
1—Thermometer
1—Triangle
6—Watch Glasses, assorted sizes
1—Alcohol Lamp, or Bunsen burner
4—Beakers (50, 100, 150 & 250 ml)
1—Test Tube Holder
1 pr.—Crucible Tongs
4 boxes—Filter Paper
1—Boiling Flask (round bottom)
1—Glass Funnel
1—Graduate
1—Ringstand, with rings & clamp
Assortment of Glass Tubing
Assortment of Rubber Stoppers
1—Test Tube Support
1—Thistle Tube
Assortment of Rubber Tubing
2—Wire Gauzes, asbestos center
1—Inexpensive Balance
1—Brush (for cleaning test tubes)
2—Crucibles, with covers (porcelain)
4—Evaporating Dishes (glass & porcelain)
4—Flasks (50, 100, 150 & 250 ml)
1—Distilling Flask (with side-arm)

Reagents

The choice of reagents is more difficult, for this will depend entirely on the general type of experimenting you expect to do. Again, we supply only the "basic" reagents:

Acetic Acid, Hydrochloric Acid, Nitric Acid, Sulfuric Acid, Ethyl Alcohol, Methyl Alcohol, Aluminum Sulfate, Ammonium Chloride, Ammonium Hydroxide, Barium Chloride, Benzene, Calcium Carbonate, Calcium Chloride, Calcium Oxide, Carbon Disulfide, Charcoal (powdered), Cobalt Chloride, Cupric Oxide, Cupric Sulfate, Hydrogen Peroxide, Ferric Chloride, Ferrous Sulfate, Lead Acetate, Magnesium Metal, Manganese Dioxide, Mercuric Chloride, Nickel Sulfate, Phenolphthalein, Potassium Bromide, Potassium Chlorate, Potassium Dichromate, Potassium Ferrocyanide, Potassium Hydroxide, Potassium Iodide, Potassium Nitrate, Potassium Permanganate, Silver Nitrate, Sodium Acetate, Sodium Bisulfite, Sodium Carbonate, Sodium Chloride, Sodium Hydroxide, Sodium Silicate, Sodium Sulfide, Strontium Nitrate, Sulfur, Stannous Chloride, Zinc Chloride.

In choosing reagents, it is well to remember that substitutions can often be made. For example, most sodium salts can be used in place of potassium salts and vice versa. It is not necessary to stock both sodium and potassium bromide or both sodium and potassium dichromate. It is usually necessary to stock only one salt of the less familiar metals, such as cobalt chloride or strontium nitrate. Also, you can make a number of reagents from those which you have. For example, if you need calcium nitrate, it can be made by dissolving calcium oxide in nitric acid. Or if you should need magnesium carbonate, it can be made by the action of sodium carbonate with magnesium sulfate (Epsom salts).

We trust the above has been of some help to you and we hope that you will find many happy and beneficial hours of experimenting in your new lab.

First Ice Cubes of Heavy Water

➤ Ice cubes of heavy water, often mentioned as an important ingredient for thermonuclear experiments, have been produced for the first time.

Heavy water is oxygen combined with deuterium or heavy hydrogen instead of normal hydrogen and is very useful in the piles which are being built to produce useful energy from atomic power. By freezing the heavy water, deuterium is found to be more concentrated than in unfrozen water.

The production of "heavy ice," a scientific feat long sought after by researchers, was obtained by violent agitation during a period of slow freezing, Drs. Hilton A. Smith, University of Tennessee, and John C. Posey of Union Carbide and Carbon Chemical Company told a recent meeting of the Southwide Chemical Conference.

Although there is no immediate use for the heavy water ice cubes, the freezing process proves "conclusively," the scientists said, that the predicted concentration of heavy hydrogen by freezing actually does take place. Experiments showed that the frozen heavy water concentrated the deuterium in amounts 2% higher than found in unfrozen water.

Sugar As a Source
Of Industrial Raw Material

The Progress of Sucrochemistry

by JOHN L. HICKSON, *Ph.D., Assistant to the President of Sugar Research Foundation, Inc.*

➤ SOME 2,200 years ago an historian, recording the campaigns of Alexander the Great, commented on an amazing "honey grass" discovered in the mystic land of India. As far as we can determine, this is the earliest recorded mention of sugar in one of its common sources—the sugar cane. And even today geneticists comb the area from the Indus to the Ganges for wild varieties of sugar cane which might offer some desirable trait when bred into commercial cane varieties.

From Luxury to Staple Food

Sugar was, for many centuries, a luxury available only to the rich, or as a medicine. Chinese physicians prescribed it for disorders of child bearing, and for purifying the blood. Queen Elizabeth introduced the custom of placing a sugar bowl on the table.

The culture of sugar cane spread from India into Egypt. From Spain, Columbus is reputed to have brought it to the West Indies on his second voyage. Since then, the culture of sugar cane has spread a belt around the globe, on both sides of the equator.

By the time Napoleon had consolidated France and was testing the defenses of his neighbors, his subjects had become accustomed to sugar. Britain's blockade of continental Europe cut off the West Indian sugar supply, and one of Napoleon's gifts to posterity was a beet sugar industry created to satisfy France's sweet tooth. The industry collapsed when the blockade was lifted, but after a span of years it was revitalized and has grown to the extent that more than a third of the world's sugar cane now comes from the beet.

With the advent of the industrial revolution and the adoption of such equipment as multiple-effect evaporators, vacuum pans an basket centrifuges, reductions in the cost of production and increases in the buying power of the masses transformed sugar from a luxury into a staple. In this country, the per capita consumption of sugar rose rather rapidly until the early 1920's when it reached 97 pounds. At that point consumption leveled off, and has been relatively constant ever since.

It might well be asked if Americans, with their high standard of living, consume the most sugar. The answer is "no." Cubans and the English Commonwealths eat more sugar than we do, but Americans outrank Continental Europeans, South Americans, Africans, and Asians. In 1955, the average per capita consumption, excluding China, was estimated at 39 pounds for a total consumption of 37 million tons. Preliminary estimates

place the 1956 total world production of sugar at more than 50 million tons. In the United States, about 9 million tons of sugar were distributed in 1956 — an all-time record.

Sugar as a Raw Material

In modern times, it is evident, sugar has become a common food, and it is likely to continue so into the future. Nevertheless, with the organization of Sugar Research Foundation in 1943, more and more attention has been given to sugar and its by-products as raw materials for both food and non-food products.

Honey

Undoubtedly the oldest chemical derivative of sugar is honey. Blossoms are visited by honey bees collecting nectar, which is a dilute solution of sucrose. The bee adds a trace of invertase and evaporates most of the water to yield honey, a solution of invert sugar, prized as a food long before man could write.

Alcohols and Acetone

Perhaps the second product from sugar was ethanol. Early fermentations undoubtedly were accidental, but man must have been quick to learn from nature, for the use of alcoholic beverages is known the world around to primitive and civilized people alike. In the tropics it is not uncommon for a small sugar mill operator to employ a part of his molasses in his own plant for the production of rum.

In this country, virtually all industrial alcohol was made from molasses until the evolution of petrochemistry revealed ethylene to be a more economical source. At present, only two fermentation ethanol plants continue to operate in this country — one on the Pacific Coast and one on the Atlantic Coast.

In 1914, fermentations of molasses by several *Clostridia* were discovered to produce N-butanol and acetone. The process was commercialized by Commercial Solvents, and has been a principal source of these important solvents.

Glycerol

Glycerol is produced as a by-product in all ethanol fermentations. The problems of isolation from the still residues raises the costs so high that recovery is not practical. However, in 1911 C. J. Neuberg, discovered that if sodium bisulfite were added to the fermentation, the ethanol pathway would be inhibited and a larger yield of glycerol would result. Yet, because of difficulties in isolation, fermentation glycerol just can't compete at today's prices.

One major chemical company has revived German studies of hydrogenolysis glycerol. It reports that sorbitol and mannitol (produced by hydrogenation of invert sugar) can be split economically by hydrogenolysis to give substantial yields of glycerol. The company reports further that the economics of the process compete quite satisfactorily with the Shell allyl chloride process and even with the recently-announced hydrogen peroxide oxidation of acrolein. The company expects to construct a plant employing the process.

Citric Acid

In 1893, Carl Wehmer announced that certain *Aspergilla* would produce citric acid from molasses. Continued process improvement broke

the virtual monopoly of the citric acid market held by the Italians, who extracted the acid from lemons. Chas. Pfizer & Company in 1923 became suppliers of the product. Chemical companies in many countries catering to the world-wide growth of the soft drink business have gone into production of this interesting organic acid.

Another off-spring of citric acid is aconitic acid, which has been prepared by dehydrating citric acid. In 1877, it was discovered to be present in cane molasses, appearing to be a characteristic of immature cane. Aconitic is isolated from Louisiana molasses by precipitation of a calcium-magnesium double salt and regeneration of the salt to the acid. It is employed principally in the synthesis of Nekal NS, a valuable wetting agent. More could be used in other ways but it isn't available.

Dextran

One more example of the use of sugar. For centuries the sugar mill owners were plagued with a gelatinous scum which formed in juices during grinding interruptions, plugging filters and preventing crystallization. The offending mold was identified as *Leuconostoc mesenteroides*. The properties of the gel were studied and production methods evolved. By the time of the Korean War, the product dextran was made available to the Armed Services, in large quantities, as a blood volume extender.

Sugar By-Products

So much for sugar itself. Let us turn to the by-products of its manufacture. Sugar beet by-products need concern us only briefly. Some of the beet molasses is treated for the extraction of monosodium glutamate, and some is favored in certain fermentations for its relatively high nitrogen content and freedom from invert sugar. With those exceptions the beet by-products are totally consumed in cattle feeding.

Bagasse

In sugar cane there is quite a different problem. After the sugar bearing juice is expressed from the cane, the fibrous residue is bagasse. Its dry weight is about equal to that of the sugar produced. On this basis we can estimate that the domestic industry produces about three million tons of bagasse each year.

At present, begasse is used chiefly as fuel to supply power for the sugar mill itself, but with efficient boilers, about 60 per cent of the bagasse is enough to provide this energy. Hence, about a million tons of domestic bagasse could be made available for other purposes.

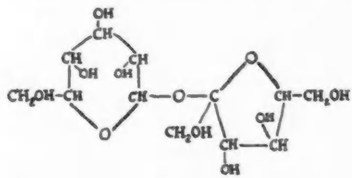
In Louisiana and Hawaii, some of the bagasse is converted into sound and thermal insulating board of the Celotex type. In Hawaii part of the production is bound with resins and pressed into a hard board, similar to Masonite. Further expansion of these uses has been limited by the expense of transporting the products to the centers of population.

In 1954 the South Porto Rico Sugar Company, in cooperation with the Quaker Oats Company, initiated a furfural operation in the Dominican Republic. Expansion of production has been limited only by the restricted market. Furfural now is used in refining lubricating oil and in the syn-

thesis of hexamethylene diamine for 6,6-Nylon.

Bagasse paper projects have been studied for scores of years. The Filipinos, Peruvians, South Africans, Australians and Indians have been operating plants for some time. In 1954, the Valentine Sugar Company in Louisiana started the first bagasse-paper mill in the United States. A dozen or so paper mills have been announced, or are being constructed in Cuba, Puerto Rico, and in Central and South America. It is reasonable to expect that bagasse will assume an increasingly important role in satisfying our burgeoning demand for paper and pulp.

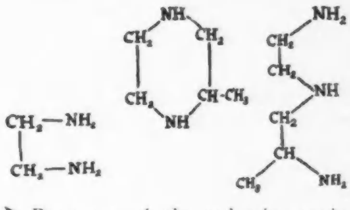
This recital could be extended beyond reason by telling you about the production of phonograph records from bagasse resin, the use of sugar in lime-sand mortar, sorbitol as a humectant, mannitol hexanitrate as a primary explosive, and others. Instead, I choose to step over into some current studies of the Foundation, which seem to me to demonstrate the potentials of sucrochemistry.



➤ SUCROSE — *the sugar molecule.*

Current Research

In pursuing research, there really are only two kinds of questions—the "I wish" and the "I wonder" types. The second of these is illustrated by our research at Penn State with Philip Skell. We said, "I wonder what happens if sugar, dissolved in anhydrous ammonia, were hydrogenerated?" What would be your guess?

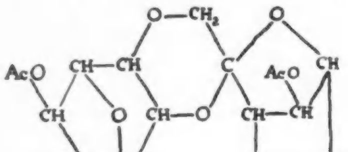


➤ PRODUCTS *of the reductive aminolysis of sugar.*

We found out that the water is almost completely removed from the sugar. The chains of 6 carbons are broken down into two and three carbon units, which turn out to be diamines. Some 15 per cent of them can be recovered as ethylene diamines, 35 per cent as piperazines, (principally 2-methylpiperazine). The remaining 50 per cent are probably linear dimers and trimers of ethylene and proplylene diamines. We are trying diligently at Penn State and at the Sondes Place Research Institute in England to unravel the mixture, since markets for the lower boiling 50 per cent are encouraging.

A second "I wonder" came up when R. U. Lemieux of the University of Ottawa studied the ionic replacability of a sucrose tritosylate. The literature reveals that the p-toluene sulfonyl groups are located in the three primary hydroxyl groups of sucrose. All should be easily removable. Lemieux discovered that two came off without much difficulty. When conditions were made more drastic, the third came off, but the

product was not sucrose. Instead a new bridge between the hexose moities had been found. The 3,6-2,1[1]-3[1],6[1]-trianhydrosucrose is still too new for us to guess at its utility.



► 3,6-2,1[1]-3[1],6[1]-*trianhydrosucrose,* 4,4[1] *diacetate*

What could you do with it? One possible use might be as a rigid glycol for the polyester resin business. At the University of Bristol, we are seeking alternate ways of bridging the moities, since the potentials of sucrose as a polyol appear quite attractive.

We have discovered that sucrose octalinseedate is an excellent drying oil. It dries quickly to give a paint surface that has good self-cleaning properties. Our sample was made from the linseed acid chlorides, a quite uneconomical process. Now we believe that we have a more economical process.

Plastics from Sugar

In the plastics field we are working out one of our "I wish" questions. The Paley report of 1952 estimated that by 1975 the plastics business would reach the 8 million ton level. You can see that if sugar achieved any significant part of that market it could improve the sugar business by a significant percentage.

The patent records divulge a large number of hopeful attempts to make plastics from sugar. You can heat sugar and phthalic anhydride and get a carbonaceous mess. We found this out too. You can heat sugar with adipic acid and zinc chloride and get the same result. But, we find that sucrose can work into phenol-formaldehyde plastic compositions to yield light-colored compositions with attractive properties and low cost. We have a bonding resin to make a plywood in which the wood will break before the resin lets go. These are in early stages of development, but sugar will find a big market in plastics.

Pesticides

Sugar appears useful in pesticides. The concept was an "I wonder." What would happen if known toxaphoric groups were added to the sucrose molecule through ester or ether linkages? One prominent pesticide chemist has estimated that in pesticides research you can only expect to find about one compound out of a thousand having desirable pesticide properties. Out of our first twenty-three, we have found a miticide, a herbicide and a rodenticide.

Surfactants

The Foundation's big pay-off to date, however, is an "I wonder" of Dr. Henry B. Hass, our President. He sat in his office one day in 1952 and asked himself how sugar could be employed as the hydrophyllic moiety of a surfactant. He took the problem to Foster D. Snell's laboratory. Two years later Snell's people knew how. You make a mono-fatty ester of it. By the next year we knew how to get a practical yield.

The process is as follows: The fat is converted to its methyl ester and glycerol is recovered as a salable by-product. The methyl ester, sucrose and some potassium carbonate are dissolved in an organic solvent. (Dimethylformamide works nicely.) Heated for about 15 minutes at about 100° C. and 100 mm pressure, the methanol is driven off and recovered. The product is about two-thirds monoester and one-third diester. If the reaction mixture is equilibrated at 100° C. and atmospheric pressure for about an hour, the ester is reconverted into more than 90 per cent of mono derivative. The unreacted sugar is separated by solvent partition and returned to the process, and the ester is dried to give solid products with attractive properties.

First they are inexpensive. Processing cost will vary with the scale of production. If you make a little, it might be 15 or 20 cents, if you make a lot, it can drop to 3 or 4 cents. Materials cost will vary with the fat chosen. For tallow the materials cost will not be over 10 cents. For cocoanut oil, the materials cost will be about 12.5 cents. If you need a specific fatty acid ester you will have to pay for it. Second, the products appear to be quite useful. For example, they all are solids. They are good detergents, excellent emulsifiers, moderate to poor foamers, and quite satisfactory wetting agents. Both moieties are food products and our preliminary evidence is that the digestive system has ample capacity to break the ester bonds of useful concentrations.

With this parade of properties we have been besieged with requests for samples and flooded with expressions of interest on the part of producers. Four foreign companies have taken out licenses — one in Denmark, two in France, and one in Cuba. Three domestic licenses have been issued. Two elect temporary anonymity. The third is Berkeley Chemical Company of New Jersey.

Production by two domestic and one foreign licensee is expected before early Spring of 1957. If this is realized we will have broken, by a significant amount, the usual seven years from test tubes to tank car. I guess you might say we are lucky and in some ways I'll agree with you. However, we at the Foundation take this as confirmation of our belief that sugar is a vast reservoir of chemical products which remains virtually untapped. We are at about the stage of development that petrochemistry found itself in the middle 1920s.

The World's Food Problem

I should like to probe into another of the Foundation's endeavors. We in this country, who take in our full 3,000 calories per day, represent a minority of the earth's population. Most people go to bed hungry.

You will recall that I pointed out that the American consumption of sugar was 97 pounds. In India it is about 27, in China less than 3. Could we feed them with more sugar?

At first glance this appears a real possibility. Under intensive cultivation, such as practiced in Hawaii, the production of crystallized sugar in 1955 was equivalent to 10.74 tons per acre. But because of the 22 month growing season this is equal to 5.86 tons per acre years. Including tops, leaves, bagasse, and molasses, the total

TABLE I
PRODUCTION OF
VARIOUS CROPS

	Tons per Acre Year
Wheat	0.5
Corn	1.1
Potatoes (dry basis)	1.75
Refined Beet Sugar	2.3
Beet Tops (dry)	1.07
Beet Pulp (dry)	0.64
Beet Molasses (dry)	0.25
Sugar Beets	4.23

crop yield was a staggering 14 tons per acre year.

On the United States Mainland, the beet sugar crop averaged 2.3 tons per acre year. Tops, pulp, and molasses added to this gave a total crop yield of 4.23 tons per acre year. Compare those data with United States averages for corn, wheat, and potatoes. (Table I)

A Source of Protein?

It would be tempting to say, "Feed them sugar." However, in a marginal economy, animals are too inefficient producers of protein and the center of the diet becomes rice, wheat or millet. These grains don't have much protein, but it is enough if slightly supplemented with fish, meat or milk. However, it would be submarginal at normal rates of growth or energy utilization. Hence, the prime nutritional need appears to be protein. One type of program suggested is to supply amino acid supplementation but as Dr. R. R. Williams so eloquently points out — the cost is prohibitive.

We are seeking to couple sugar's amazing productive capacity to an animal agriculture to provide meat and milk for these people. The least expensive form of nitrogen available for microbial synthesis of protein in ruminants is ammonia. In the laboratory of Karl M. Herstein of New York we learned how to ammoniate sugar beet pulp to raise its protein equivalent from about 9 per cent (a poor protein source) to over 18 per cent (an excellent protein source for cattle). The Amalgamated Sugar Company in Utah has spent two years in feeding tests and report that cattle grow faster on ammoniated beet pulp than on cottonseed meal. The cost of the beef is reduced by the substitution. Trials with dairy cattle are in progress at the National Institute for Research in Dairying at Shinfield, England. This should help make meat and milk available in temperate climates, such as China.

Bagasse has posed a more difficult problem. Here we have worked with the pith which is about 30 per cent of the material and which must be separated for utilization of the bagasse fiber in pulping operations. At the United States Sugar Corporation in Florida, we found out how to add some 12 per cent of protein value by ammoniation. Feeding tests at the University of Florida reveal the ammoniated bagasse to be equal in value to most grass hays.

By adding meat, milk and sugar to the marginal diets of the hungry hordes, the Foundation seeks to make its contribution to humanity. We are pleased there appears to be so bright a future for sucrochemistry.

Inventors Reveal New Methods and Processes

New Chemical Patents

To obtain copies of these new patents, order them by number from the Commissioner of Patents, Washington 25, D. C. Enclose 25 cents in coin, money order or Patent Office Coupons (but not stamps) for each patent ordered.

Solid Plates of Titanium

➤ TITANIUM and zirconium should be more plentiful soon.

The invention relates to a new form of the metals that is particularly suitable to melting and alloying. The form is solid plates and is very different from either the spongy or particulate forms of titanium and zirconium now used in metallurgical processes.

Dr. Reginald S. Dean of the Chicago Development Corporation, Riverdale, Md., the inventor, told Science Service that the process will "at first be important for the recovery of the metals from scrap and then work over to makea large contribution to the production of titanium and zirconium from ore."

Dr. Dean's process, much improved since its earliest development, will go into operation in a pilot plant now being built by Mallory-Sharon Titanium Corp., Niles, Ohio.

The invention provides for the first time a solid form of titanium that can be readily separated from the electrode by mechanical means, and which may be directly melted and alloyed to produce metal of excellent properties. Dr. Dean points out in his patent that the article produced with his process results in a virgin metal; a metal produced for the first time from compounds of titanium and not from other forms of titanium by mechanical work. This distinguishes it, he states, from plates which might be formed by rolling or hammering titanium sponge particles or melted material.

The solid plates of titanium and zirconium were granted patent No. 2,785,066. Dr. Dean assigned the patent rights to the Chicago Development Corporation of Riverdale, Md.

Chemicals From Bark

➤ KENNETH RUSSELL GRAY and Hartzell Lance Crosby of Shelton, Wash., appear to have barked up the right trees. They received patent No. 2,782,241 for a process whereby tree bark can be made to yield valuable chemical products.

The researchers used the bark from Western hemlock, Douglas fir, Western white fir, Sitka spruce and Southern yellow pine and treated them individually and blended. The results were polymeric products that can be used in place of simple phenols in many cases; as deflocculants that are superior to tannins; and as effective drilling mud additives.

The chemical products are obtained by digesting the bark in a water solution of an alkali hydroxide at a temperature of from 65 degrees to 185 degrees Centigrade. The inventing team assigned the patent rights

to Rayonier, Incorporated, of Shelton, Wash.

Germanium From Coal

➤ COAL IS a mineral storehouse, containing many of the earth's rare and minor elements. One such hidden element found in coal is germanium, the mineral that made the tiny transistor possible.

A Japanese inventor, Masaru Inagaki of Tokyo, has invented a process for recovering germanium-containing material from the liquor formed during the high temperature carbonization of coals.

Mr. Inagaki saves the valuable germanium from the waste material by forming a precipitate from which pure germanium compounds and metal can be obtained. The process, he says, can be used to treat gas liquor from any source provided the germanium content is about 0.001 gram per liter, estimated to be sufficient to justify the expense. Mr. Inagaki was awarded patent No. 2,786,750 and assigned the patent rights to the Coal Research Institute of Tokyo, Japan.

Almost Pure Silicon

➤ ONE OF the ingredients of the tiny transistor, which earned its three American inventors the Nobel Prize in Physics this year, is silicon. Now, silicon has been produced in a form that is 99.9 plus percent pure.

The almost pure silicon in a coarse crystalline form is the result of a reduction process invented by Dr. Keith Huestis Butler of Marblehead, Mass., and Carl Marcus Olson of Newark, Del. The silicon thus prepared by their process, the scientists say, "is eminently suited to a wide variety of uses in the electrical industry. Indeed, the high purity of the silicon attained by our process is so unique that the development of the silicon junction transistor and large area power rectifiers would not have been possible without it." The inventors were granted patent No. 2,773,745 and assigned the patent rights to E. I. du Pont de Nemours & Company of Wilmington, Del.

Rocket Propulsion Method

➤ A FAMILY of jet fuels that can be used without the need of an auxiliary ignition system to ignite the propellants has been found. Incorporated in a rocket propulsion method, it provides more effective and efficient jet propulsion systems; an oxidizing agent which is easily combustible with a suitable fuel and which has a large amount of oxygen available for burning a fuel; and eliminates the danger of explosion.

The invention of Frank J. Malina and John W. Parsons of Pasadena, Calif., the rocket propulsion method uses white fuming nitric acid as its oxidizer and one of four groups of compounds that make up the family of fuels discovered to do the job.

The compounds, that may be utilized as fuels, are liquid organic compounds such as aniline; highly unsaturated hydrocarbons such as propargyl alcohol; liquid substances with properties of the elements lithium, beryllium, boron, aluminum, magnesium, phosphorus, potassium and sodium; and organic compounds having the properties of pyrrole, pyridine, pinene, terpene, pinol, terpinol, hydrazine, ozonides, and carbon disulfide containing phosphorus.

The inventors, who were awarded patent No. 2,774,214, prefer aniline,

they say. They assigned the patent rights to Aerojet-General Corporation of Cincinnati, Ohio.

All-Purpose Detergent Bar

➤ HOUSEWIVES will be pleased to learn that an all-purpose, safe-to-use detergent bar has been invented by a team of researchers.

The detergent bar, as described by its inventors, lathers in water of any degree of hardness from zero to the hardness of sea water and at any temperature of from zero to 100 degrees Centigrade. It can be used for dishware and kitchen utensils; for hand laundering of clothes; as a general purpose toilet soap and for shaving soap.

Perhaps of equal importance to the detergent bar's all-around-the-house utility, it is further described as "non-toxic and non-irritating to the human skin." The detergent bar is made from synthetic organic chemicals and can have added to it suitable binders, fillers, perfumes, salts, colors, fungicides, germicides and antiseptics.

The invention of Charles F. Jelinek and John Yeager of Easton, Pa., and Raymond L. Mayhew of Phillipsburg, N. J., the detergent bar was awarded patent No. 2,781,320. The inventing team assigned the patent rights to General Aniline & Film Corporation of New York, N. Y.

Growing Quartz Crystals

➤ SYNTHETIC quartz crystals weighing more than one pound have been grown in the laboratory in less than two months. The method used for their growth earned Ernest Buehler of Chatham Township, N. J., patent No. 2,785,058.

The quartz crystals produced, Mr. Buehler says, can be grown to sufficient size for piezoelectric use. In the process, crystalline quartz is used as the nutrient in an aqueous medium and the growth of the seed crystal is dependent upon the small temperature differential maintained between the medium around the seed and the medium around the nutrient.

The quartz nutrient is slowly dissolved in the aqueous solvent at the higher temperature and the dissolved silica is then deposited on the quartz seed at the lower temperature. The entire process, however, is carried out at both high temperatures and high pressures. What results is a rate of growth at about one-tenth of an inch per day, for long periods of time.

Mr. Buehler assigned the patent rights for his invention to the Bell Telephone Laboratories, Inc., of New York, N. Y.

Fuel From Wastes

➤ THE COMBINATION of two waste products has promised a useful product that can be used to fuel the nation's industrial furnaces.

Coal silt, a waste product of coal mining, is treated with spent sulfite, a waste from the paper-making industry. The action of the sulfite on the silt results in the formation of a small size fuel that can be used commercially. The invention of Waldemar Hartmann of Mountain Lakes, N. J., it is believed that the process enables operators to exploit a resource that heretofore has been uneconomical to use. Coal silt, Mr. Hartmann points out, is now banked in large dumps near collaries as waste. He was granted patent No. 2,778,718.

Book Condensations

THE CHEMICAL HISTORY OF A CANDLE — Michael Faraday, foreword by E. N. daC. Andrade and biographical introduction by Sir J. Arthur Thomson — *Crowell,* 158 p., illus., $2.75. These lectures were presented as one of the famous Christmas Children's lectures at the Royal Institution in London in 1860.

CHEMISTRY: The Conquest of Materials — Kenneth Hutton — *Penguin,* 228 p., illus., paper, 85 cents. A small book for the layman on the materials used by chemists and what they can make out of them.

ALCHEMY — E. J. Holmyard — *Penguin,* 281 p., illus., paper, 85 cents. The forerunners of modern nuclear physicists were changing one substance into another in China four centuries before the birth of Christ.

SCIENCE IN THE MAKING — Joel H. Hildebrand — *Columbia University Press,* 116 p., illus., $3.00. In these lectures, the author, an outstanding chemist, indicates that the scientist needs no special "method." What he needs is ingenuity and determination and plenty of experimentation.

A SCIENTIFIC SAMPLER — Raymond Stevens, Howard F. Hamacher and Alan A. Smith — *Van Nostrand,* 415 p., illus., $6.00. A selection of reports, predictions and reflections chosen from the 30-year file of the Arthur D. Little *Industrial Bulletin.*

MODERN CHEMISTRY FOR THE ENGINEER AND SCIENTIST — G. Ross Robertson, Ed. — *McGraw-Hill,* 442 p., illus., $9.50. Lectures originally given as part of an extension course at the University of California. Each contributor was selected as a recognized research scholar widely known as a contributor in his field.

THE PROSPECTS OF NUCLEAR POWER AND TECHNOLOGY — Gerald Wendt — *Van Nostrand,* 348 p., illus., $6.00. Written for businessmen, legislators, and leaders of thought to help them comprehend and evaluate this great new force and what it means to mankind. The author is a writer on science for UNESCO.

LIVING CHEMISTRY — Maurice R. Ahrens, Norris F. Bush and Ray K. Easley — *Ginn,* 2d rev. ed., 582 p., illus., $5.28. This beautifully presented book is intended to make the study of chemistry a "living experience" for high-school students.

ELEMENTARY PRACTICAL ORGANIC CHEMISTRY — Part I. Small Scale Preparations — Arthur I. Vogel — *Longmans, Green,* 347 p., illus., $4.50. The first part of an elementary text concerned with small-scale preparations.

THE CHEMICAL INDUSTRY FACTS BOOK — *Manufacturing Chemists' Association,* 149 p., illus., paper, $1.25. History and statistics of the industry and a glossary of terms used.

Neutron Absorbing Isotope For Civilian Atomic Energy

Boron-10 Available

► BORON-10, the light-weight isotope of boron that makes up about 20% of naturally occurring boron, is now being offered for sale by the Atomic Energy Commission. The special advantage of this isotope is that boron-10 captures very readily and absorbs them without itself becoming radioactive.

The nuclear reaction that takes place when an atom of boron-10 captures a neutron results in the formation of a staple isotope of lithium, of atomic weight 7, without emission of dangerous gamma rays or high-energy particles.

Used as Neutron Shield

This property of absorbing neutrons makes boron-10 valuable as a shield against radiation composed of neutrons. Boron-10's sister isotope, boron-11, which makes up the other 80% of natural boron, does not capture neutrons with the same enthusiasm. A given thickness of pure boron-10 will absorb over 5 times as many neutrons as natural boron. For this reason, the separation of boron-10 from boron-11 is now being carried out in a government-owned plant operated by the Hooker Electrochemical Company at Model City, N. Y. Recent technical improvements have raised output to the point where kilogram amounts of boron-10 can be offered to sale to non-government users. The plant produces about 20 pounds a week of metallic boron-10, a dark gray powder resembling graphite and valued at nearly three times the price of gold.

Separation by Fractionation

Although the nuclear properties of boron-10 and boron-11 differ greatly, their chemical properties are the same. Separation of the two isotopes must be based on the slight difference in their atomic weights. The process used in the Model City plant is somewhat similar to the fractionation processes used in the petroleum industry.

Boron trifluoride, a gas which is available commercially, is used as a source of boron, and is reacted with liquid dimethyl ether to form a liquid complex. The liquid is then pumped through a series of fractionation columns equivalent to a single column 350 feet high. Continuous recycling of the liquid, with the application of heat, cooling, and vacuum in each column, concentrates liquid containing boron-10 at the bottom of the last column. The boron-11 flows backward through the columns to the first one.

A separation takes a minimum of 30 days to complete. When the liquid enriched with boron-10 complex has reached the assay required, it is drawn off. The enriched boron is then precipitated as potassium fluoroborate, and boron metal is separated by electrolysis.

The Model City plant can produce enriched boron at assays ranging from 30% to 90% boron-10.

The chief use of boron-10 in the past has been in control rods in nuclear reactors. In chain reactions, fission is caused by bombardment with neutrons, the amount of atomic energy produced depending on the neutron flux within the reaction chamber. Control rods, made of material that can absorb neutrons without causing fission or radiation, are thrust into the chamber to regulate the neutron flux. Boron-10 is used in carbon or steel control rods in the form of boron carbide or a boron-steel alloy.

In the future, with more of the isotope available, boron-10 is expected to be used more for shielding nuclear reactors, especially where weight and size are at a premium, as in mobile power plants. A given thickness of boron-10 is 20 times as effective as lead and 500 times as effective as concrete, and has the added advantage of weighing less than either one.

Boron-10 is also expected to be useful in the measurement of neutron radiation. Some work has already been done on a boron-10 dosimeter, a safety device that indicates the amount of radiation to which the wearer has been exposed.

On the Back Cover

➤ A SYNTHETIC *sapphire is grown from aluminum oxide powder by the flame fusion process. The four stages shown cover a time span of about twenty minutes.*

Powdered aluminum oxide is heated by an oxyhydrogen flame to a temperature just below its melting point. The flame, which can be seen as a faint streak near the crystal, is hollow. It is directed downward onto a pedestal. The powdered oxide is dropped through the center of the flame in small amounts, falling on the pedestal and becoming fused.

When the melted powder reaches a certain temperature, it forms a molten ball called a boule. The material changes from a powder to a crystal very quickly, and the crystal continues to grow.

Invented in 1895 by August V. L. Verneuil, of France, the flame fusion process, despite its antiquity, remains the most practical method for producing metal oxide crystals. It is used commercially for the mass production of synthetic sapphires, rubies, and spinels.

These photographs were taken at the Crystal Laboratory, Magnetics Section, of the Naval Ordnance Laboratory, White Oak, Maryland, where basic research is being conducted on the magnetic properties of single crystals. Using the flame fusion process, the Crystal Laboratory has grown single crystals, large enough for testing, of several ferrites and of the antiferromagnetic compound chromic oxide. In the future, such crystals may be used in transformers and antennas of ultra-high-frequency electronics communications or in memory units of electronic computers.